LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONFLUENCE SITES
CONCEPTUAL DESIGN REPORT

August, 1985

Prepared For:

Alberta Environment
Planning Division

Prepared By:
W-E-R Engineering Ltd.
in association with
Thurber Consultants Ltd.
and
Nanuk Engineering and Development Ltd.

August 30, 1985

Alberta Environment
Planning Division
200 - 5 Avenue South
Lethbridge, Alberta
T1J 4C7

Attention: Mr. Sandy Larsen, P.Eng.

Re: Little Bow River Basin
Storage Investigation, Confluence Sites
Conceptual Design Report

Dear Mr. Larsen:

We are pleased to submit herewith five copies of our interim report entitled "Little Bow River Basin Storage Investigation, Confluence Sites - Conceptual Design Report", August, 1985.

W-E-R Engineering Ltd. wishes to acknowledge the involvement of Thurber Consultants Ltd. and Nanuk Engineering and Development Ltd. in providing the geotechnical and hydrological analyses included in this report.

Based on the results of this conceptual design study, Site 78-1 has been selected for the feasiblity investigation. Accordingly, we are now proceeding with the feasibility design stage of this investigation.

This has been a most interesting and challenging assignment. We welcome any questions that may arise as a result of this work.

Yours very truly,

W-E-R ENGINEERING LTD.

J.M. Wise, P.Eng.
Vice-President

JMW:pc

PROFESSIONAL ENGINEER J.M. WISE

THE ASSOCIATION OF PROFESSIONAL ENGINEERS GEOLOGISTS and GEOPHYSICISTS OF ALBERTA
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SYNOPSIS

This report describes the conceptual design studies carried out by W-E-R on three storage alternatives located below the confluence of the Little Bow River and Mosquito Creek.

The total estimated costs for the three reservoir alternatives are as follows:

	Storage Capacity (Acre-Ft.)	Project Cost	Cost per Ac.Ft.* of Basin Yield
SITE 7A	50 000	$12,871,000	$169
SITE 7B	41 000	$10,947,000	$153
SITE 7B-1	50 000	$11,303,000	$149

The report recommends retention of Site 7B-1 for feasibility stage studies.

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*Based on new guidelines and 300 cfs diversion capacity. Does not include cost of increasing diversion capability.

TABLE OF CONTENTS

		Page No.
1.0	INTRODUCTION	1
2.0	HYDROLOGIC ASSESSMENT	3
	2.1 Water Supply	3
	2.2 Flood Flows	4
3.0	GEOLOGICAL/GEOTECHNICAL OVERVIEW	6
	3.1 Bedrock Geology	6
	3.2 Surficial Geology	6
	3.3 Buried Valleys	7
	3.4 Implications for Construction	7
	3.5 Embankment Designs	8
4.0	CONCEPTUAL DESIGN	9
	4.1 General	9
	4.2 Reservoir Sizing	9
	4.3 Embankment Design	10
	4.4 Spillways	10
	4.5 Low Level Irrigation Outlet Works	10
	4.6 High Line Irrigation Canals	11
	4.7 Basis of Costing	11
5.0	RESERVOIR COSTS	12
	5.1 Land Acquisition	12
	5.2 Reservoir Damages	12
	5.2.1 Roads and Bridges	12
	5.2.2 Utilities	13
	5.2.3 Farm Buildings	13
6.0	CONCLUSIONS AND RECOMMENDATIONS	14
	6.1 Little Bow Site 7A	14
	6.2 Little Bow Site 7B	14
	6.3 Little Bow Site 7B-1	15

LIST OF FIGURES

Figure No.	
1	Location Plan
2	General Layout - Little Bow Site 7A
3	General Layout - Little Bow Site 7B
4	General Layout - Little Bow Site 7B-1
5	Potential High Line Canal Locations

LIST OF TABLES

Table No.	
1	Project Data and Cost Estimate Summary -Little Bow Site 7A
2	Project Data and Cost Estimate Summary -Little Bow Site 7B
3	Project Data and Cost Estimate Summary -Little Bow Site 7B-1

LIST OF APPENDICES

A - WATER SUPPLY AND HYDROLOGY STUDY

B - PRELIMINARY GEOLOGICAL AND GEOTECHNICAL ASSESSMENT

C - PRELIMINARY COST ESTIMATE ANALYSIS

D - RESERVOIR DAMAGES AND LAND ACQUISITION

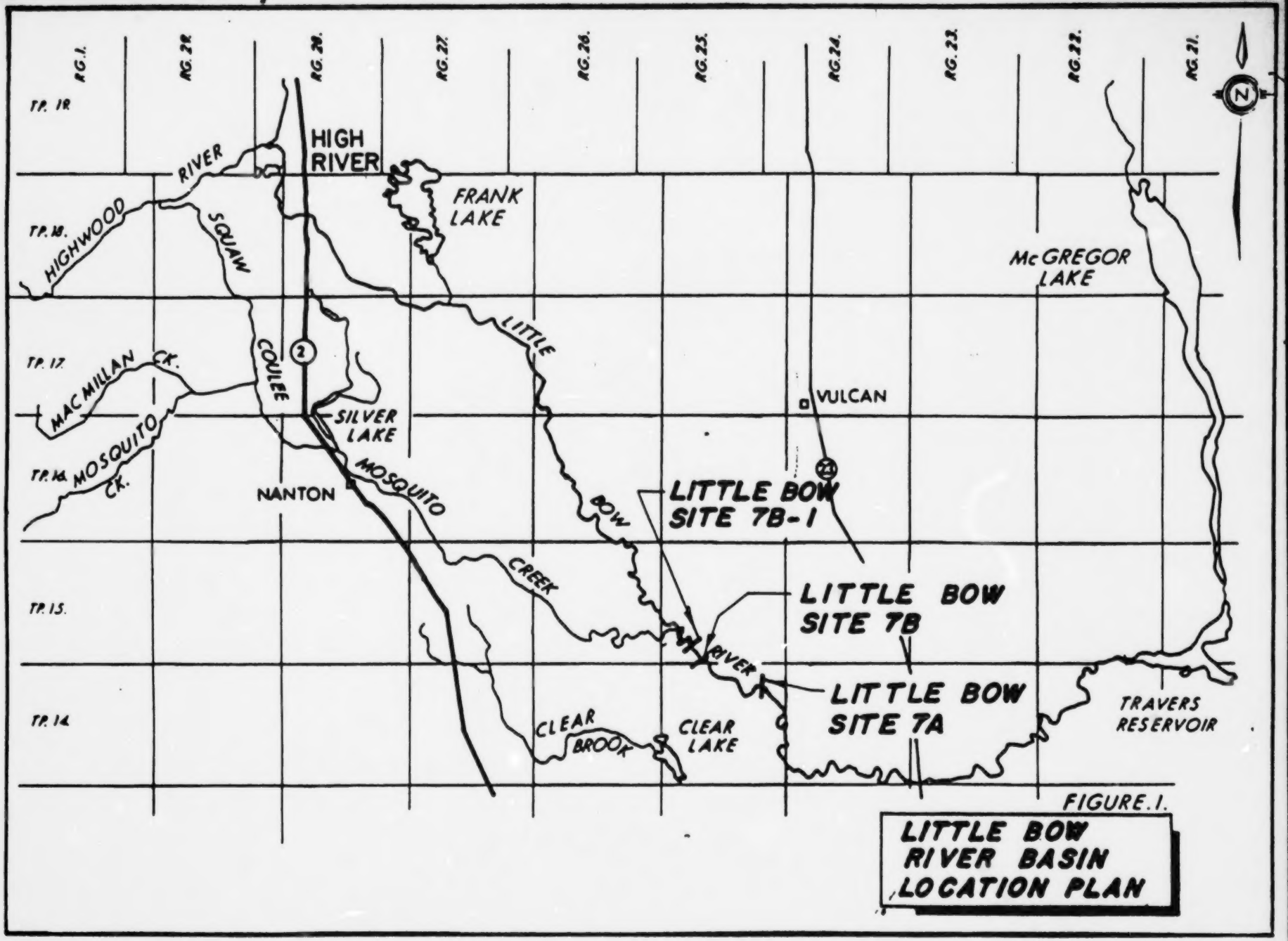


FIGURE. 1.

LITTLE BOW RIVER BASIN LOCATION PLAN

1.0 INTRODUCTION

Extremely high irrigation demands in the Little Bow River Basin in conjunction with low flows in both the Little Bow and Highwood River systems, particularly over the last two years have intensified the need for water storage facilities in the Little Bow River Basin.

Previous studies by W-E-R Engineering Ltd. examined at the feasibility level (Reference 1), three potential storage sites in the upper reaches of the system located on Squaw Coulee, Mosquito Creek, and the Little Bow River upstream from the confluence.

This present report describes the results of conceptual design studies for three additional reservoir alternatives, all of which are located on the main stem of Little Bow River downstream from the confluence with Mosquito Creek as shown in Figure 1. All of the reservoir investigations referred to above form part of the overall Phase II Little Bow River Study, which is being directed by the Alberta Environment Planning Division.

In the current study, the reservoir storage capacities which are in the range of 49,400 to 61,700 dam^3 (40,000 to 50,000 ac.ft) have been maximized based on topographic limitations, and in accordance with a revised total maximum diversion guideline of 60% of Highwood River flows. The diversion rates at Squaw Coulee are still limited to the present system capacity of 1.7 m^3/s (60cfs), however, several capacities of the Little Bow Diversion were examined, ranging from 2.8 m^3/s (100 cfs) to 8.5 m^3/s (300 cfs). The suitability of the three reservoirs as supply sources for high line irrigation canals has also been evaluated in this study.

This summary report compares each of the three sites from the standpoint of water supply capability, geotechnical considerations, structure layout and design, reservoir damages, land acquisition, and costs of implementation. The study results have been summarized in the form of design layouts, pertinent data and a comparison spreadsheet at the back of the main report.

Details of each of the component studies which include hydrology, geotechnical, design and reservoir damage overviews are provided in Appendices A through D. On the basis of these conceptual investigations, recommendations for subsequent feasibility studies for the selected reservoir site are presented.

2.0 HYDROLOGIC ASSESSMENT

A conceptual level water supply and flood flow assessment of the three confluence sites was conducted as a part of the current study. The results were used in support of the reservoir and spillway sizing for each of the storage sites. Details of this hydrologic assessment are provided in Appendix A.

2.1 Water Supply

The water supply capability of the three potential reservoir sites was evaluated in terms of the total water supply that could be made available, primarily for irrigation uses, over a range of storage capacities. No differentiation was made between sites since only natural runoff would vary.

a) Base Data

Water available from the Highwood River for the Little Bow was based on two sets of operational guidelines. One stipulated that diversions could not exceed 40% of the flow in the Highwood River. The second sets increased the percent diverted to 60% but required a residual flow of 2 m^3/s (70 cfs) in the Highwood River downstream of the diversion to the Little Bow canal. Several capacities of the Little Bow canal were analysed, whereas the Squaw Coulee diversion was set at 1.7 m^3/s (60 cfs). The operating season was assumed to be April 15 to October 15.

b) Methodology and Results

The period 1916 to 1941 was selected for the water supply study, since it included the most critical drought period on

record. For this period of record, water balance studies were conducted for the confluence site, which considered inflows (diversions plus natural inflows) evaporation losses, municipal and riparian requirements, and water releases for irrigation.

Based on these studies the hydrologic optimum capacities from a water supply standpoint were determined for the two guidelines and three canal capacities. These optimum capacities are as follows:

Guideline	Little Bow Canal Capacity m^3/s (cfs)	Hydrologic Optimum Capacity dam^3 (ac-ft)	Basin Supply dam^3 (ac-ft)
10% & 30%	2.8 (100)	22 000 (18,000)	46 900 (38,000)
60% & 2 m^3/s	2.8 (100)	24 600 (20,000)	51 800 (42,000)
60% & 2 m^3/s	5.7 (200)	32 000 (26,000)	67 800 (55,000)
60% & 2 m^3/s	8.5 (300)	40 000 (33,000)	80 200 (65,000)

A 61 600 dam^3 (50,000 ac.ft.) reservoir at any confluence site will produce a basin yield of 65 800 (53,000 ac.ft.) at a capacity of 2.8 m^3/s (100 cfs) in the Little Bow Canal. A 5.7 m^3/s (200 cfs) canal will increase the yield to 83 900 dam^3 (68,200 ac.ft.) and a 8.5 m^3/s (300 cfs) canal capacity produces a 93 500 dam^3 (76,000 ac.ft.) yield.

2.2 Flood Flows

Flood frequency analyses were carried out for use in the design of spillways and construction diversion works for each site. The probable maximum flood (PMF) for all three sites was determined using Saskatchewan-Nelson Basin Board data. The 1 in 100 year and 1 in 25 year floods were determined using frequency analysis from recorded flows of the

Little Bow River at Carmangay. A complete description of the methodology used can be found in Appendix A.

The flood flows for preliminary design are:

PMF
(maximum mean daily) - 566-708 m^3/s (20,000 to 25,000 cfs)

1 in 25 year
(peak instantaneous) - 85 m^3/s (3,000 cfs)

1 in 100 year
(peak instantaneous) - 147 m^3/s (5,200 cfs)

----- WATER SUPPLY AND HYDROLOGY DETAILS IN APPENDIX A -----

3.0 GEOLOGICAL/GEOTECHNICAL OVERVIEW

Geological and geotechnical conditions have been assessed at these potential "confluence" sites, designated Little Bow River sites 7A, 7B and 7B1. Detailed geotechnical information was available for Site 7B-1 from a previous study by PFRA carried out in 1971 (Reference 2). However, Sites 7A and 7B were assessed on the basis of a geological overview since testhole data were not available for these two damsites.

3.1 Bedrock Geology

The Willow Creek Formation, of Upper Cretaceous-Tertiary age, is the uppermost bedrock unit in the Little Bow River-Mosquito Creek confluence area. It comprises a non-marine sequence of shales and sandstones, with minor siltstone and bentonitic shale. In general, the bedrock at these sites is flat-lying and only moderately jointed and fractured. Favourable construction conditions are indicated.

3.2 Surficial Geology

Glacial till, consisting of clay to gravel size material deposited by a glacier, is the dominant surficial deposit in the area, frequently it is overlain, close to the river and creek valleys, by a veneer of glaciolacustrine (glacial lake) silt, sand and clay. In the area around Clear Lake, glaciofluvial kame and esker deposits, consisting primarily of sand and gravel, are widespread. In general, postglacial deposits, of alluvial and colluvial origin, are confined to the river and creek valleys (where they form floodplains and terraces, and slopewash deposits).

3.3 Buried Valleys

A number of buried pre-glacial valleys exist in this part of Southern Alberta. These valleys are of concern from a geotechnical point of view in that, if infilled with granular material, they may represent a source of water loss from reservoirs located above them as well as result in high groundwater pressures beneath the dam.

Existing data indicate that the pre-glacial Tee Pee Valley is present in the vicinity of all three sites; drilling at Little Bow Site 7B-1 has disclosed the presence of interbedded sands, silts and clays beneath till that are interpreted to be valley infill deposits. Geotechnical concerns relative to the presence of pre-existing failure surfaces within the clays and potential for seepage through the more pervious portions of this deposit are identified. The precise location of the Tee Pee Valley relative to sites 7A and 7B is unknown. However, in the event the valley underlies these sites, similar geotechnical concerns should be anticipated.

3.4 Implications for Construction

With the possible exception of the buried Tee Pee Valley, concerns with respect to which are detailed in the previous section, no geotechnical features that would have a major impact on dam and reservoir construction are identified at any of the sites. In all three instances, however, measures will be needed to control seepage through granular floodplain sediments as well as through fractured bedrock in the abutments. As far as construction materials are concerned, common fill may be obtained from the abutment areas, and random granular from floodplain/terrace deposits and the

kames and eskers around Clear Lake. Select granular can likely be obtained from local pits, rip-rap will probably need to be imported.

3.5 Embankment Designs

On the basis of the preliminary geotechnical assessment, embankments have been designed with a 6 m wide crest, and 4H:1V upstream and 3H:1V downstream slopes. Key trenches and downstream pervious filters are incorporated in each instance. Slope protection will consist of rock rip-rap underlain by a gravel bed.

------- GEOLOGY/GEOTECHNICAL DETAILS IN APPENDIX B -------

4.0 CONCEPTUAL DESIGNS

4.1 General

Conceptual designs and cost estimates were prepared for each of the three alternative sites, as shown in Figures 2 through 4 and Tables 1 through 3.

The area of the Little Bow River Valley encompassing the three alternative reservoirs was mapped at a scale of 1:10,000 with 2 metre contour intervals. This mapping was used to develop site layouts and area-capacity curves.

Detailed topographic and geotechnical information was made available by Alberta Environment for Site 7B-1 from a 1971 investigation undertaken by PFRA for the Saskatchewan Nelson Basin Board (Reference 2). That report was reviewed for this study in conjunction with the geotechnical overview of the three alternative sites as outlined in Section 3.0 and Appendix B.

4.2 Reservoir Sizing

Reservoirs were sized in accordance with the terms of reference of this study as between 49 400 and 61 700 dam^3 (40,000 and 50,000 ac.ft.), unless otherwise governed by topographic or water supply limitations (based on the new diversion guidelines of a maximum diversion of 60% of the Highwood River flows).

Sites 7A and 7B-1 were sized at 61 700 dam^3 (50,000 ac.ft.) which is below the topographic or hydrologic maximum at these sites. Site 7B was sized at its topographic maximum of 32,800 dam^3 (40,500 ac.ft.).

4.3 Embankment Design

The embankment designs are based on recommendations included in the geological and geotechnical assessment detailed in Appendix B. With the exception of Site 78-1 which was drilled by PFRA in 1971 (Reference 2), geotechnical data is somewhat limited and consequently the embankment designs may be considered conservative.

The embankment design sections for the three alternatives require 4:1 upstream and 3:1 downstream slopes and a 6 m crest width. For each alternative, allowance was made in the cost estimate for slope protection, downstream filters and a key trench extending beneath the dam into impervious foundation material.

4.4 Spillways

Conceptual designs for the three alternatives consider fixed-crest and parallel-sided reinforced concrete chute spillways which are sized to efficiently handle the routed 1:100 outflows (see Appendix A). In all cases the spillways will pass the safety-of-dam flood (0.5 x probable maximum flood) with 0.13 m of freeboard. This is in accordance with Alberta Environment's dam safety guidelines. In subsequent feasibility studies, potential cost savings resulting from the use of a gated chute spillway or a chute spillway/ emergency earth spillway combination will be evaluated.

4.5 Low Level Irrigation Outlet Works

Gated precast concrete conduit outlets are proposed for each of the reservoir alternatives. These structures would be

utilized to divert normal streamflows during the construction period and be subsequently converted to permanent outlet works for irrigation and riparian releases. Irrigation works were designed to provide 8.5 m^3/s (300 cfs) at minimum reservoir levels for all sites.

4.6 High Line Irrigation Canal

Conceptual layouts of high line irrigation canals were proposed for each of the three alternative reservoirs under consideration (Figure 5). These canal layouts are based on the assumption that 50 percent of the storage capecity of each of the reservoirs will be available for irrigation diversion to the respective high line canals with the other 50 percent of storage used for low line irrigation. Many other storage combinations can of course be considered but this was not part of the scope of the current study. Neither irrigation headworks nor canals were costed for this study.

4.7 Basis of Costing

Unit construction costs utilized in the preparation of cost estimates for this study were based on bid prices for recent tenders on similar storage projects as well as tender prices on recent major irrigation works in Southern Alberta.

---------- MAIN WORKS COST DETAILS IN APPENDIX C ----------

5.0 RESERVOIR COSTS

An assessment of the costs associated with land acquisition and reservoir damages was prepared for each of the three storage sites, primarily to provide a basis for screening and comparison of the reservoir alternatives. Details of the reservoir costs are included in Appendix D of this report.

5.1 Land Acquisition

The areas required for reservoir land control are based on the top-of-dam elevation in each case, and were measured from the reservoir plans. Unit land costs were averaged at $1980 per hectare (ha) for cultivated hay lands, and $740 per hectare for other lands. An additional 25% was added for severance and acquisition costs.

5.2 Reservoir Damages

5.2.1 Roads and Bridges

The most significant reservoir damage cost is associated with the raising of existing roads and bridges, some of which are common to all three site alternatives. Secondary Highway 529, which crosses all three reservoirs was the most seriously effected and three different alternatives for dealing with it were examined in each case. For each of the reservoirs, the least cost alternative was assumed to be acceptable in this conceptual study phase, although some alternatives involve increasing the length of the road by up to 6 km. The most costly alternative in all cases was retaining S.H. 529 at its present location. Neither municipal nor provincial authorities were consulted at this

stage. However, in subsequent phases of the study the question of road requirements should be re-assessed in detail.

5.2.2 Utilities

A three phase power line crosses the Site 7A reservoir and would require special long-span towers. Other utilities affected are of a minor nature and are described in Appendix D.

5.2.3 Farm Buildings

The study assumes that existing occupied farm buildings effected by reservoirs could be moved to new locations. The most significant of those is the Little Bow River Hutterite Colony, which contains a number of new large buildings.

--------- RESERVOIR COST DETAILS IN APPENDIX D ----------

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Little Bow Site 7A

- is the highest cost alternative;
- has the highest reservoir costs in terms of utility damages and further travel distance because of road relocation;
- floods the largest area of cultivated land;
- is the furthest downstream of the confluence sites and therefore commands the smallest irrigation area;
- has some potential seepage problems due to a possible buried valley contact, based on limited geotechnical information;

Recommendation: delete from further study.

6.2 Little Bow Site 7B

- has the smallest capacity (limited by topography) and therefore, provides the least benefits in terms of irrigation potential of the three alternatives studied;
- has the highest cost per unit of storage;
- has a higher cost/benefit factor than Site 7B-1;
- floods a greater area of cultivated land than Site 7B-1;
- has some potential seepage problems due to a possible

buried valley contact, based on limited geotechnical information;

Recommendation: delete from further study.

6.3 Little Bow Site 7B-1

- is the most cost effective site in terms of both total storage and water supply benefits;

- has the lowest reservoir costs in terms of utility damage and travel distance due to road relocation;

- is the furthest upstream site, and would therefore command the greatest irrigation area;

- has some potential seepage, settlement and stability problems, primarily on the west abutment, however, there is good testhole data available and the extent of these problems is known and can be accommodated in the final design;

Recommendation: considering the information available and the fact that geotechnical concerns can be addressed in the design, it is recommended that Site 7B-1 be retained for further study.

STUDY RESULTS

TABLE 1
LITTLE BOW SITE - 7A

PROJECT DATA

Reservoir

Full Supply Level (FSL)	959.2 m
Total Storage at FSL	61 700 dam^3 (50 000 Ac. ft)
Live Storage	60 700 dam^3
Flooded Area at FSL	800 ha
Safety-of-Dam Flood - 0.5 PMF (inflow)	322.8 m^3/s

Embankment

Top of Dam Elevation	962.2 m
Maximum Height	24.6
Volume of Fill	575 500 m^3

Spillway

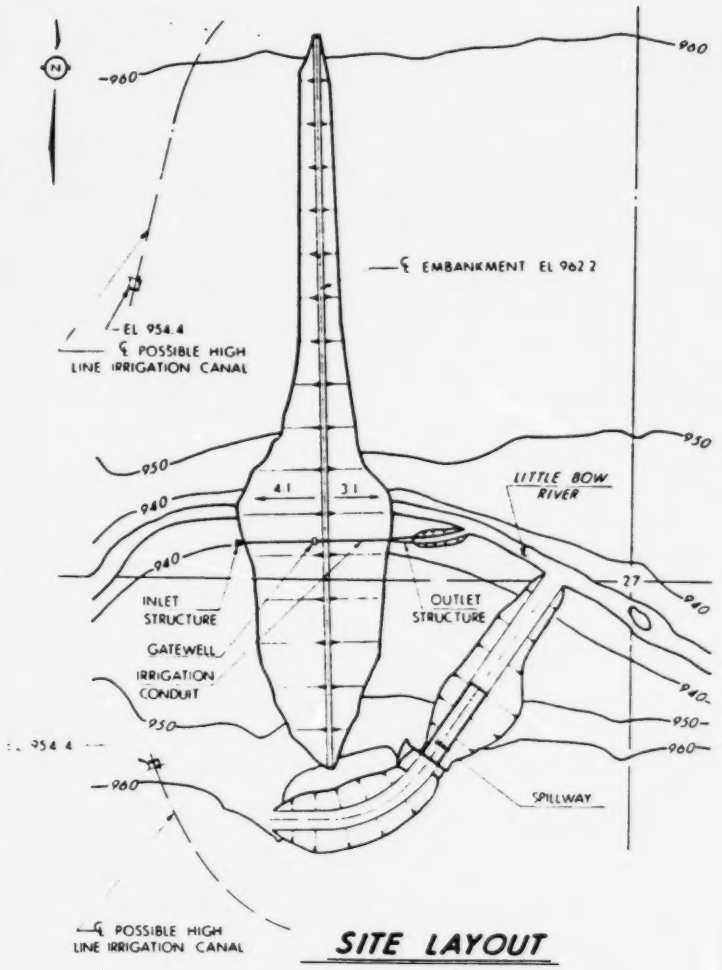
Type of Spillway	Concrete Chute
Crest Width	23 m
Crest Elevation	959.2
Spillway Design Discharge (1:100 routed outflow)	54.0 m^3/s
Safety-of-Dam Discharge (0.5 Probable maximum routed outflow)	235.0 m^3/s

Diversion and Outlet Works

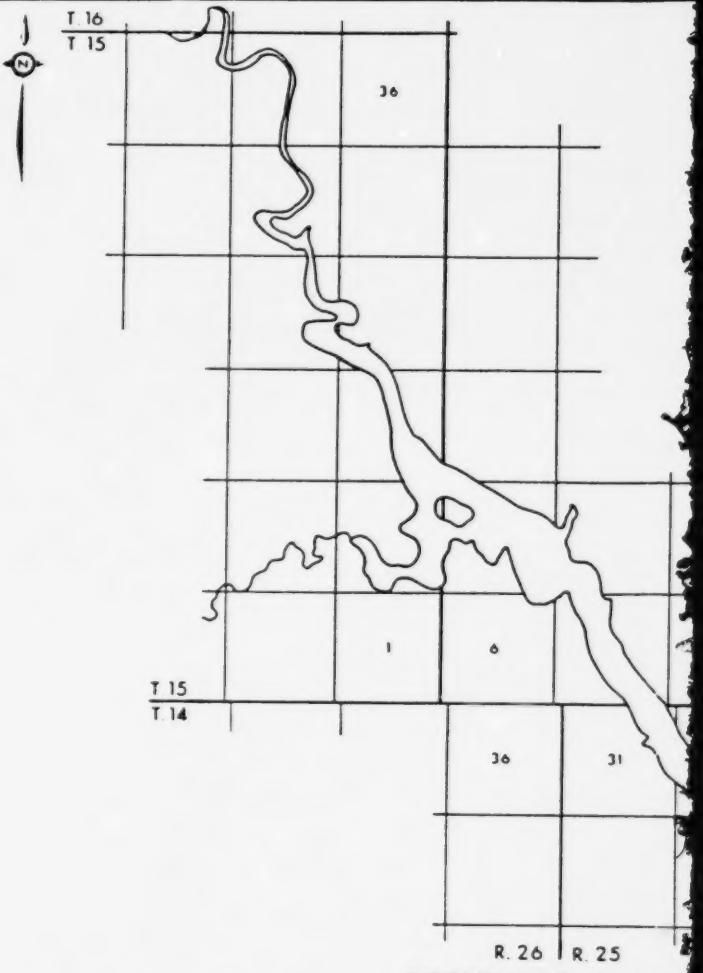
Number and Dimensions of Conduits	1 @ 1.5 m DIA.
Gates (2)	2.0 m x 2.0 m
Intake Elevation	939.6 m
Design Capacity	8.5 m^3/s
Elevation to pass design capacity (8.5 m^3/s)	944.2 m

COST ESTIMATE SUMMARY

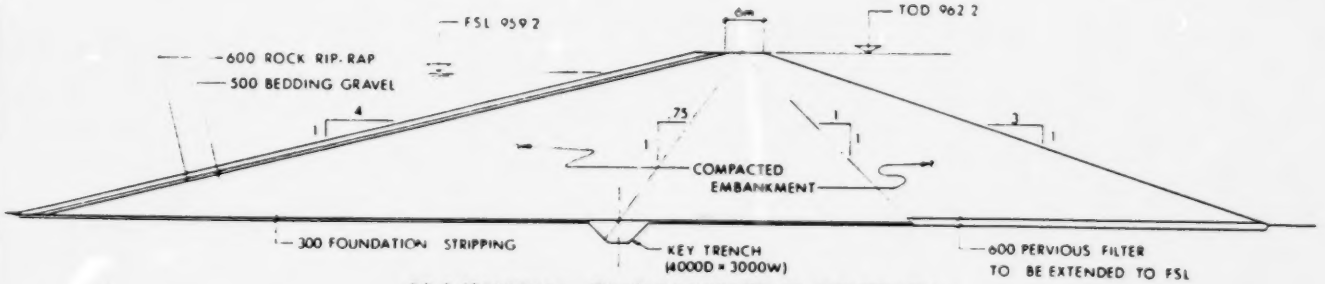
Care of Water		275,000
Embankment		3,692,000
Spillway		1,179,000
Diversion and Outlet Works		634,000
	Subtotal	5,780,000
	Contingencies (30%)	1,734,000
	Subtotal	7,514,000
	Engineering (15%)	1,127,000
	Reservoir Costs	4,230,000
	TOTAL PROJECT COST	$12,871,000



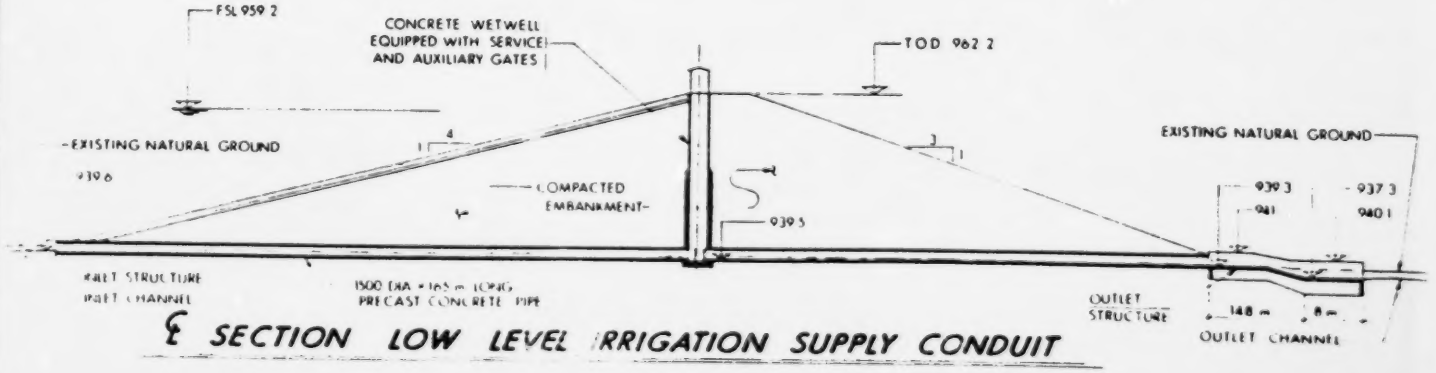
SITE LAYOUT



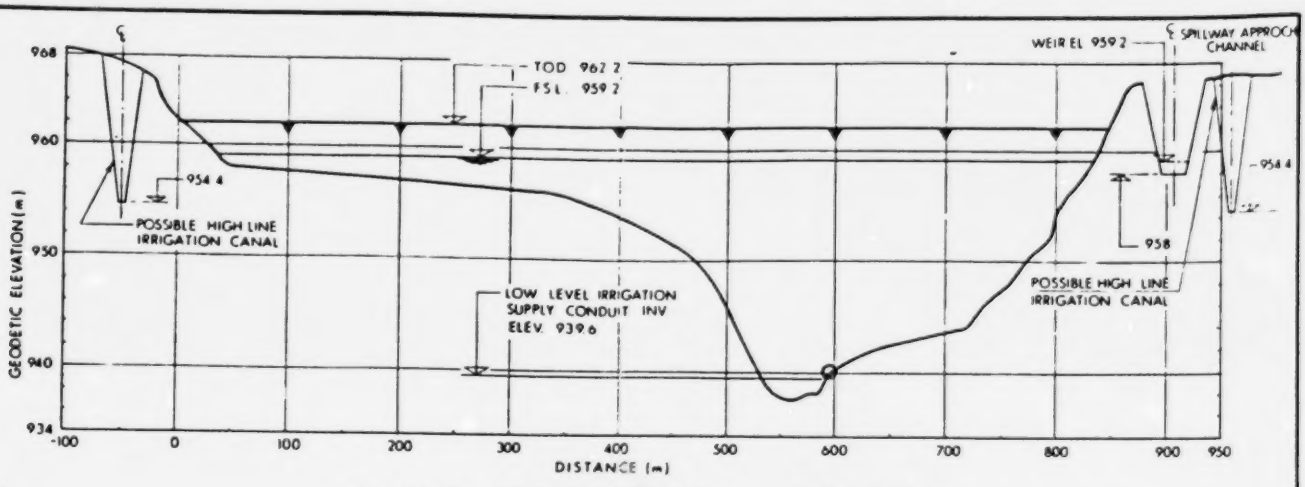
RESERVOIR PLAN



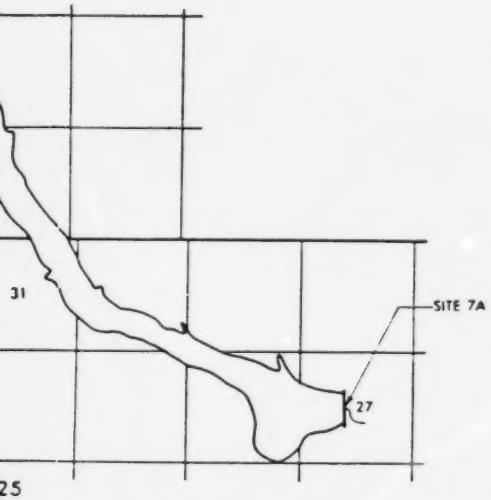
MAXIMUM EMBANKMENT SECTION



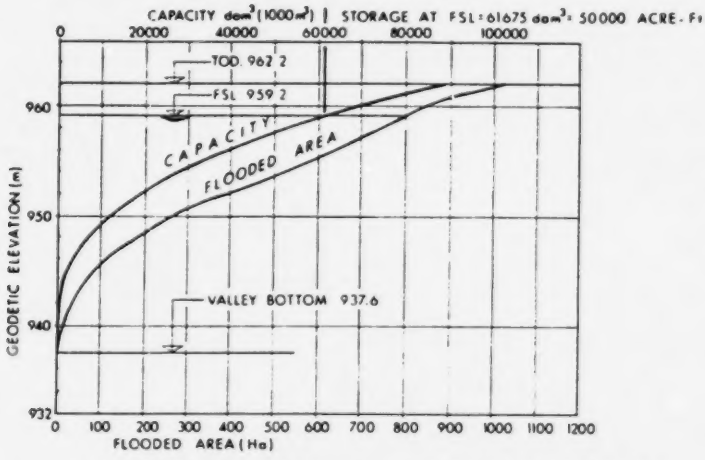
℄ SECTION LOW LEVEL IRRIGATION SUPPLY CONDUIT



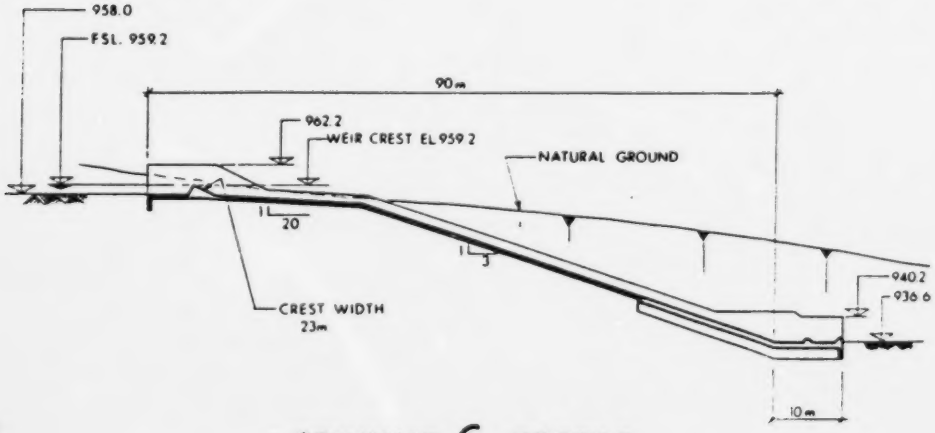
VALLEY CROSS SECTION - D/S VIEW



PLAN



FLOODED AREA & CAPACITY CURVES



SPILLWAY & PROFILE

W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT: LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
CONFLUENCE SITES

SITE 7A.
27-14-25-W4

GENERAL LAYOUT

DESIGNED	CHECKED	DATE	JOB No	FIGURE
DRAFTED L.T.J.	APPROVED	SCALE	SHEET No	2

TABLE 2
LITTLE BOW SITE - 7B

PROJECT DATA

Reservoir

Full Supply Level (FSL)	962.0 m
Total Storage at FSL	50 000 dam^3 (40 500 Ac. ft)
Live Storage	49 000 dam^3
Flooded Area at FSL	700 ha
Safety-of-Dam Flood - 0.5 PMF (inflow)	322.8 m^3/s

Embankment

Top of Dam Elevation	965.0 m
Maximum Height	20.8
Volume of Fill	417 200 m^3

Spillway

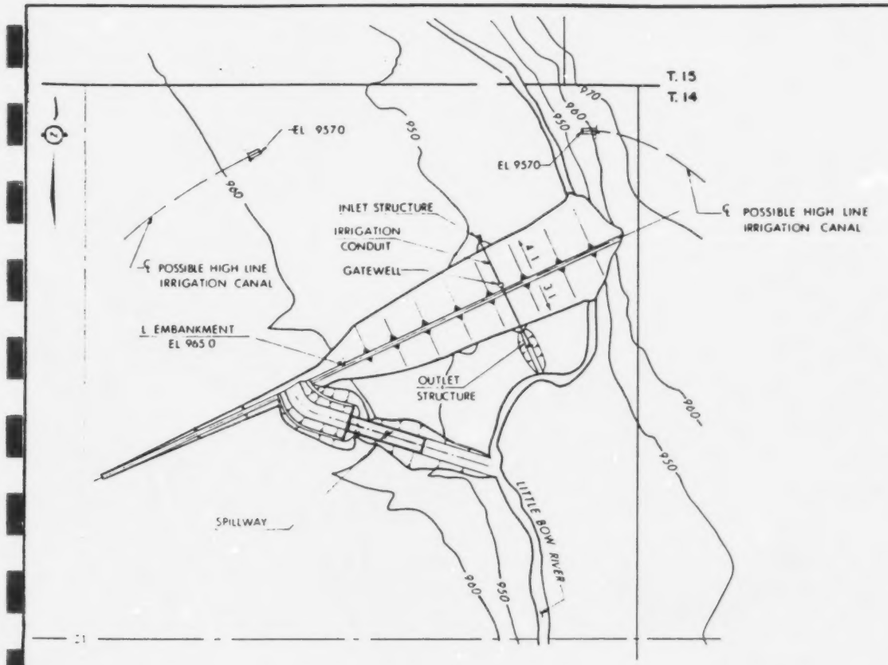
Type of Spillway	Concrete Chute
Crest Width	23 m
Crest Elevation	962.0
Spillway Design Discharge (1:100 routed outflow)	54.0 m^3/s
Safety-of-Dam Discharge (0.5 probable maximum routed outflow)	235.0 m^3/s

Diversion and Outlet Works

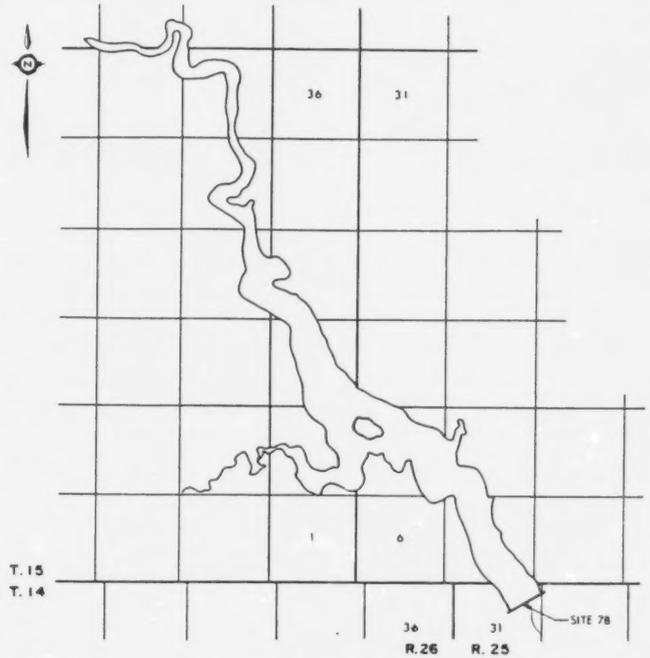
Number and Dimensions of Conduits	1 @ 1.5 m DIA.
Gates (2)	2.0 m x 2.0 m
Intake Elevation	946.0 m
Design Capacity	8.5 m^3/s
Elevation to Pass Design Capacity (8.5 m^3/s)	950.6 m

COST ESTIMATE SUMMARY

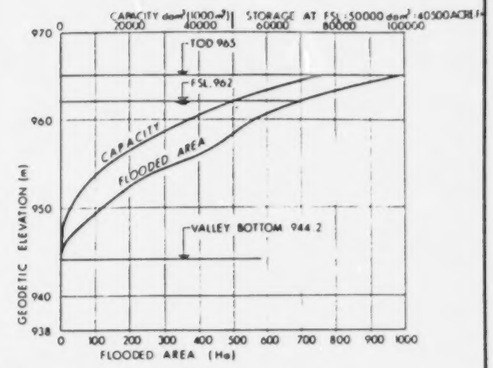
Care of Water		227,000
Embankment		2,796,000
Spillway		1,167,000
Diversion and Outlet Works		575,000
	Subtotal	4,765,000
	Contingencies (30%)	1,430,000
	Subtotal	6,195,000
	Engineering (15%)	929,000
	Reservoir Costs	3,823,000
	TOTAL PROJECT COST	$10,947,000



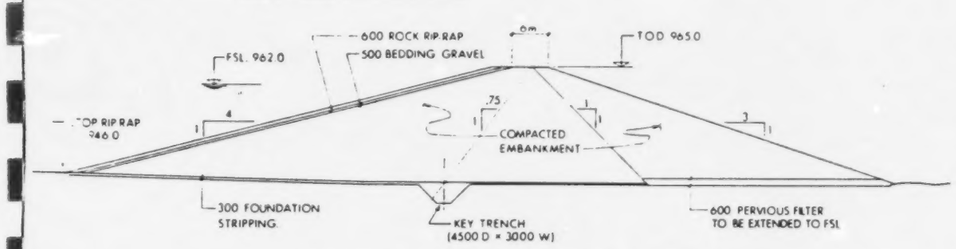
SITE LAYOUT



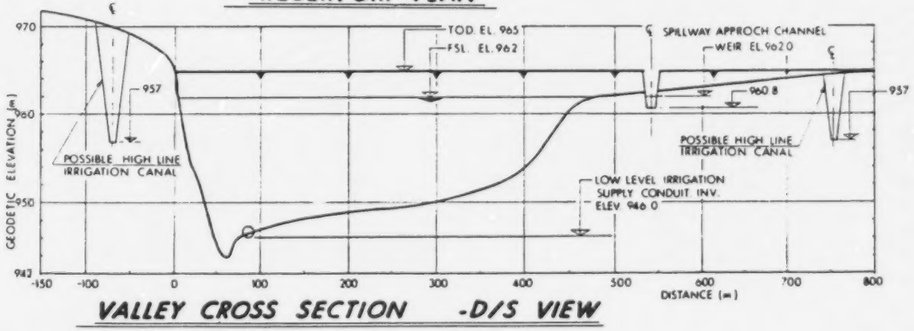
RESERVOIR PLAN



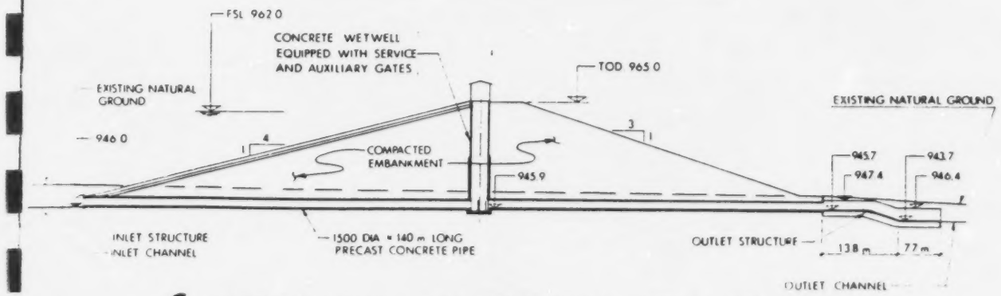
FLOODED AREA & CAPACITY CURVES



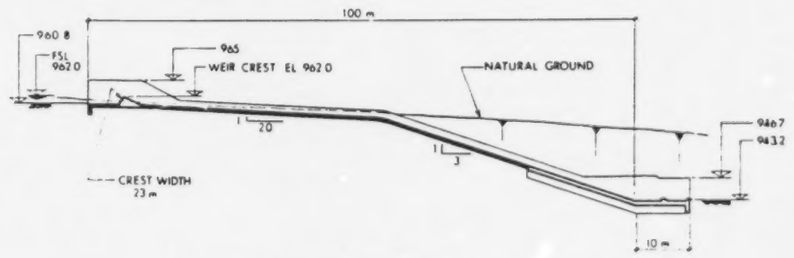
MAXIMUM EMBANKMENT SECTION



VALLEY CROSS SECTION -D/S VIEW



℄ SECTION LOW LEVEL IRRIGATION SUPPLY CONDUIT



SPILLWAY ℄ PROFILE

W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT: LITTLE BOW RIVER BASIN STORAGE INVESTIGATION CONFLUENCE SITES

SITE 7B
31 - 14 - 25 - W 4

GENERAL LAYOUT

DESIGNED	CHECKED	DATE	JOB NO	FIGURE
DRAFTED: N	APPROVED	SCALE	SHEET No.	3

TABLE 3
LITTLE BOW SITE - 7B-1

PROJECT DATA

Reservoir

Full Supply Level (FSL)	964.7 m
Total Storage at FSL	61 700 dam^3 (50 000 Ac. ft)
Live Storage	60 700 dam^3
Flooded Area at FSL	865 ha
Safety-of-Dam Flood - 0.5 PMF (inflow)	322.8 m^3/s

Embankment

Top of Dam Elevation	967.7 m
Maximum Height	22.4
Volume of Fill	500 300 m^3

Spillway

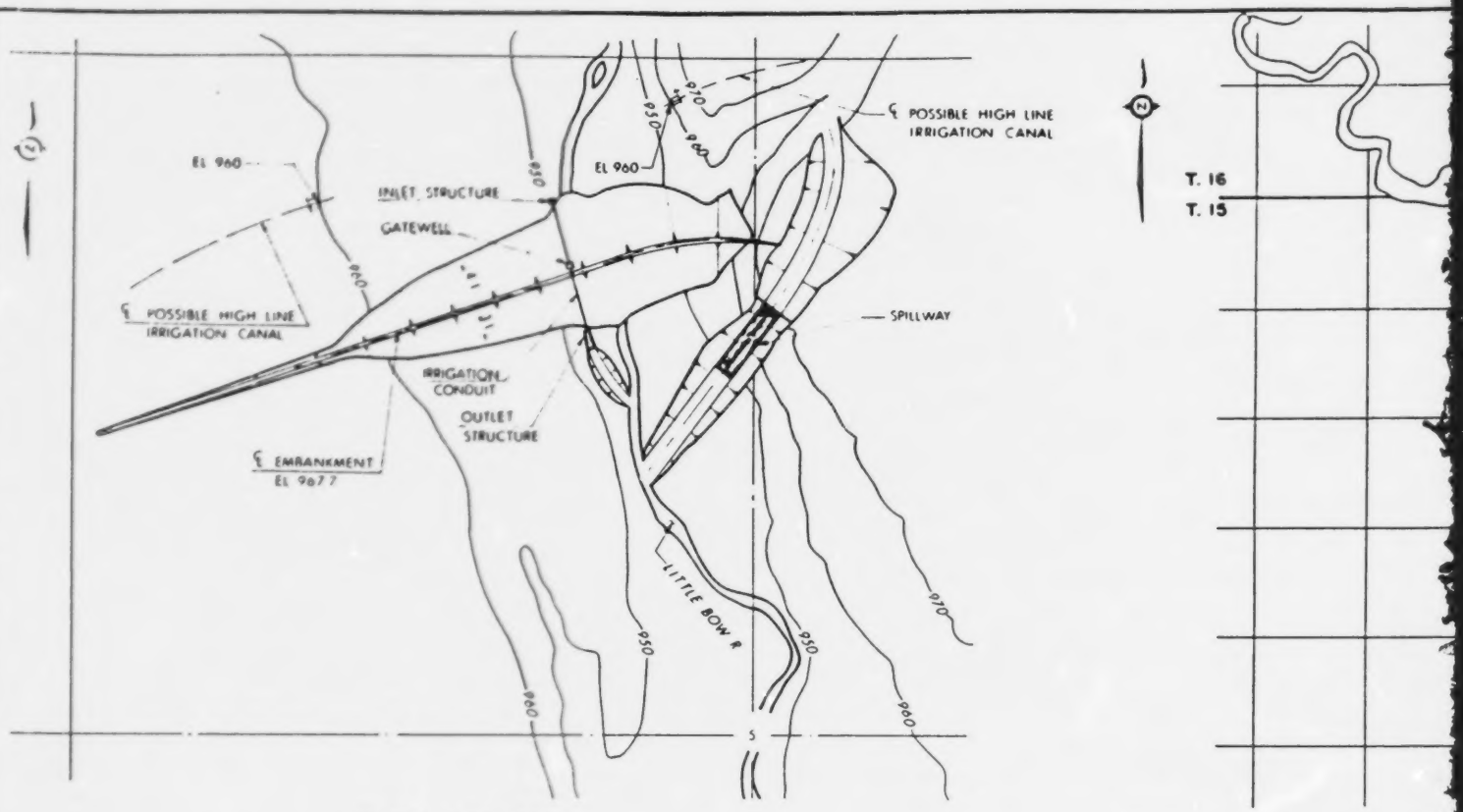
Type of Spillway	Concrete Chute
Crest Width	23 m
Crest Elevation	964.7
Spillway Design Discharge (1:100 routed outflow)	54.0 m^3/s
Safety-of-Dam Discharge (0.5 probable maximum routed outflow)	235.0 m^3/s

Diversion and Outlet Works

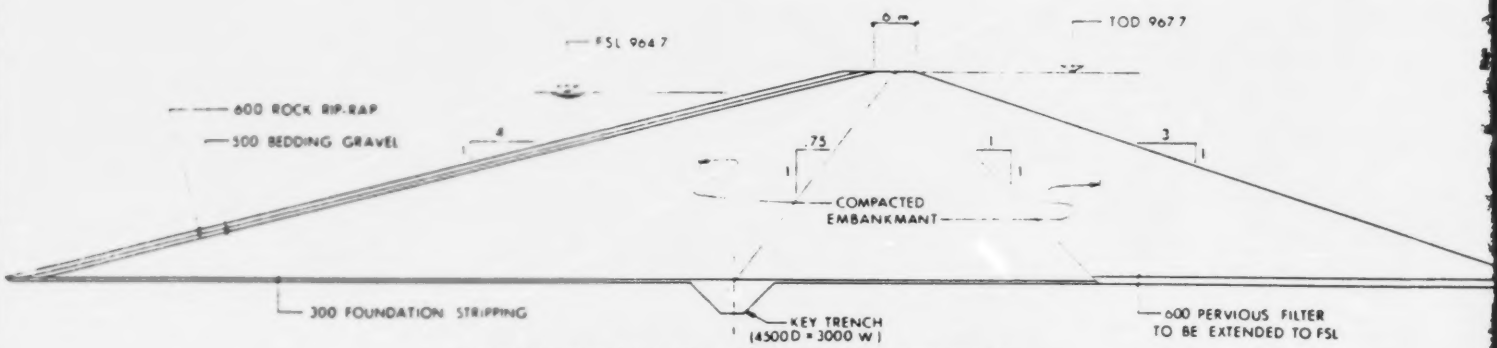
Number and Dimensions of Conduits	1 @ 1.5 m DIA.
Gates (2)	2.0 m x 2.0 m
Intake Elevation	947.3 m
Design Capacity	8.5 m^3/s
Elevation to Pass Design Capacity (8.5 m^3/s)	951.9 m

COST ESTIMATE SUMMARY

Care of Water		243,000
Embankment		3,056,000
Spillway		1,199,000
Diversion and Outlet Works		595,000
	Subtotal	5,093,000
	Contingencies (30%)	1,528,000
	Subtotal	6,621,000
	Engineering (15%)	993,000
	Reservoir Costs	3,689,000
	TOTAL PROJECT COST	$11,303,000



SITE LAYOUT



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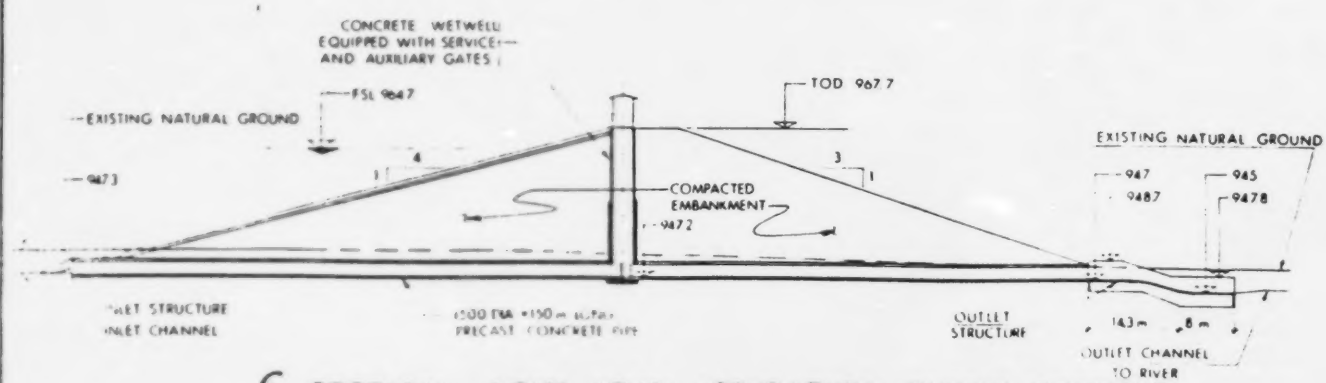

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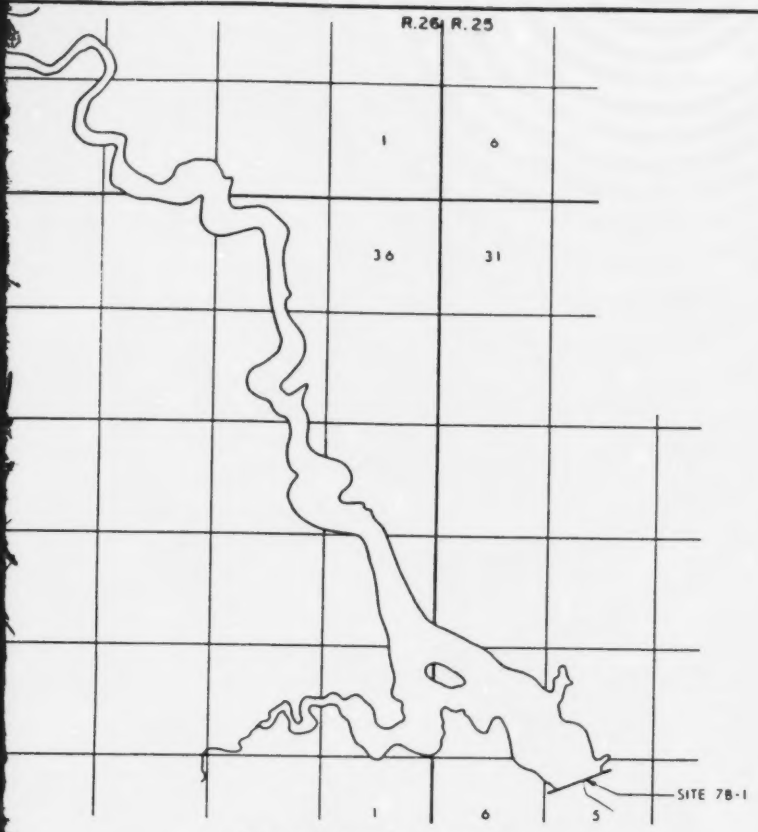
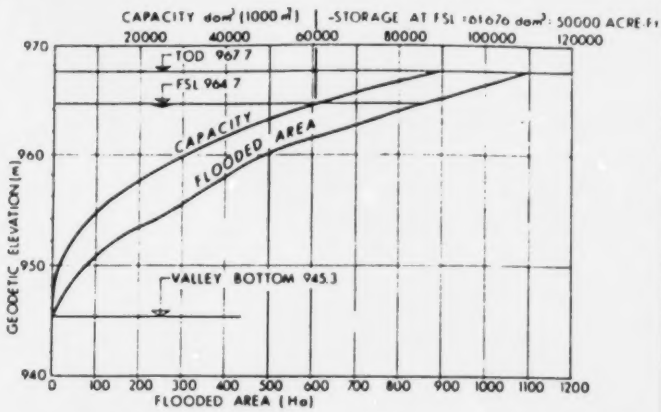
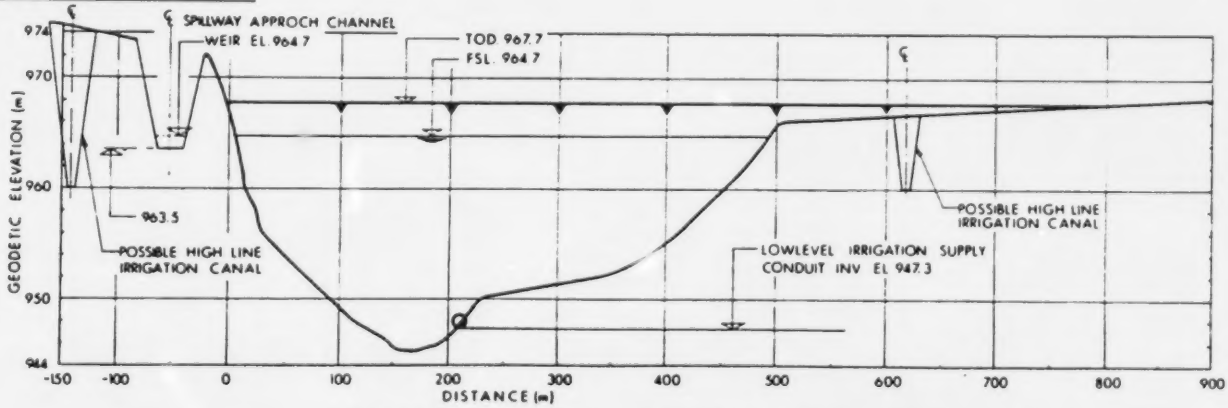


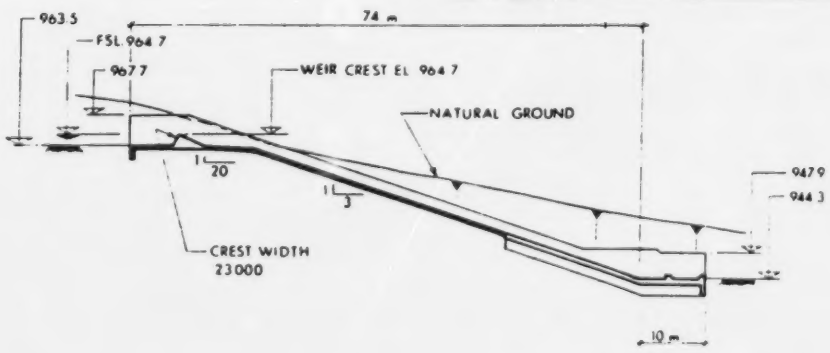
RESERVOIR PLAN



FLOODED AREA & CAPACITY CURVES



VALLEY CROSS SECTION - D/S VIEW



SPILLWAY ℄ PROFILE

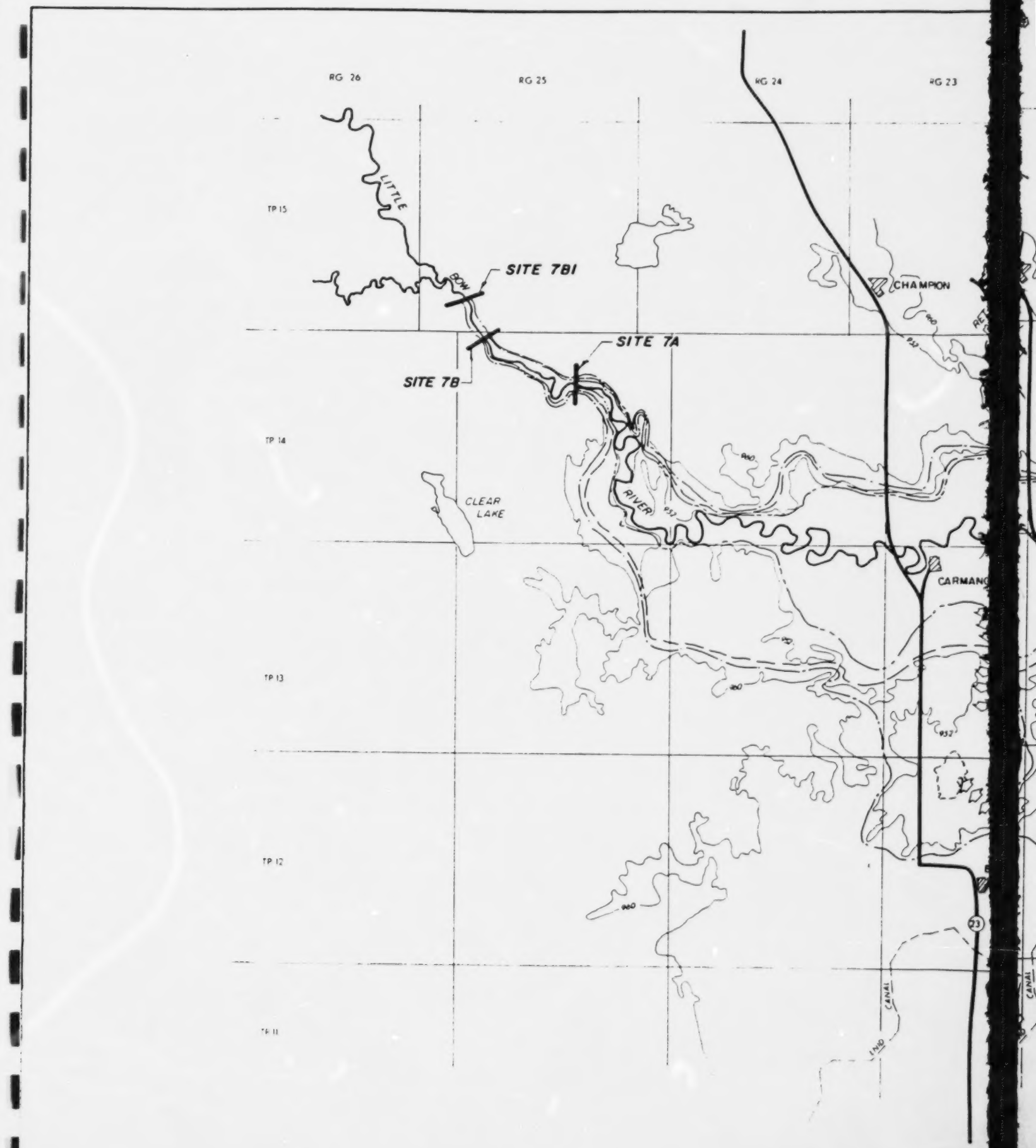
W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

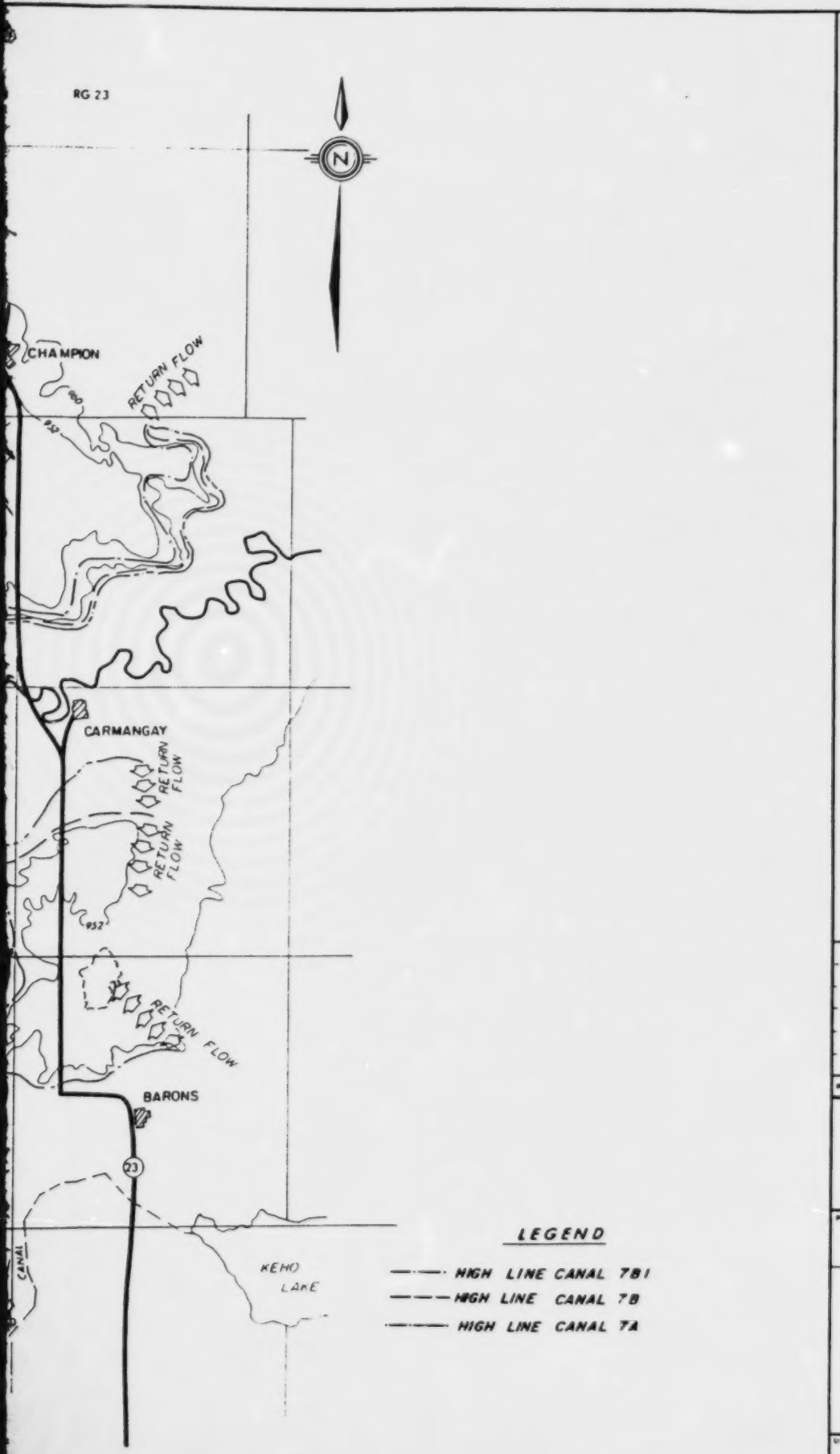
PROJECT: LITTLE BOW RIVER BASIN
STORAGE INVESTIGATION
CONFLUENCE SITES

SITE -7B1
5-15-25-W4

GENERAL LAYOUT

DESIGNED	CHECKED	DATE	JOB No.	FIGURE
DRAFTED	APPROVED	SCALE	SHEET No.	4


RG 26
RG 25
RG 24
RG 23
TP 15
TP 14
TP 13
TP 12
TP 11
LITTLE
BOW
SITE 7B1
SITE 7A
SITE 7B
CHAMPION
CLEAR
LAKE
RIVER
CARMAN
23
LINE
CANAL



Notes:

REV	DATE	REVISION DESCRIPTION	ENG	APPD

W-E-R ENGINEERING LTD.
CALGARY, ALBERTA

PROJECT: LITTLE BOW RIVER BASIN STORAGE INVESTIGATION CONFLUENCE SITES

POTENTIAL HIGH LINE CANAL LOCATIONS

DESIGNED	CHECKED	DATE	A/B No.	FIGURE
DRAFTED	APPROVED	W.A.I.D	SHEET No.	3

RESERVOIR	DAM HEIGHT (m)	FLOODED AREA AT FSL (ha)	STORAGE dam³ (acre feet)	TOTAL dam
LITTLE BOW SITE 7A	24.6	800	51,700 (50,000)	1) 2) 3) 4
LITTLE BOW SITE 7B	20.8	[illegible]	[illegible] (40,500)	[illegible]
LITTLE BOW SITE 7B-1	22.4	[illegible]	[illegible] (50,000)	1 2 3 4

STORAGE (acre feet)	TOTAL BASIN SUPPLY dam3 (acre feet)	GEOTECHNICAL OVERVIEW	RESERVO
			LAND AND BUILDINGS
700 (50,000)	1) 60,400 (49,000) 2) 66,100 (53,600) 3) 83,900 (68,000) 4) 93,700 (76,000)	-FOUNDATION ADEQUATE -SEEPAGE THROUGH VALLEY BOTTOM MAY BE PROBLEM -POSSIBLE BURIED VALLEY PROBLEM -ABANDONED HIGH LEVEL CHANNEL ON NORTH ABUTMENT	-303 ha CULTIVATED -722 ha GRASSLAND AND BUSH -3 FARMSTEADS AND HUTTERI COLONY TO BE RELOCATED
300 (40,500)	1) 57,000 (46,000) 2) 63,300 (51,000) 3) 65,000 (53,000) 4) 88,000 (71,000)	-FOUNDATION ADEQUATE -SEEPAGE THROUGH VALLEY BOTTOM MAY BE PROBLEM -POSSIBLE BURIED VALLEY UNDER DAMSITE	-266 ha CULTIVATED -734 ha GRASSLAND AND BUSH -3 FARMSTEADS AND HUTTERIT COLONY TO BE RELOCATED
700 (50,000)	1) 60,400 (49,000) 2) 66,100 (53,600) 3) 83,500 (67,700) 4) 93,700 (76,000)	-POTENTIAL SETTLEMENT AND STABILITY PROBLEM IN WEST ABUTMENT -POSSIBLE SEEPAGE INTO BURIED VALLEY SEEPAGE THROUGH VALLEY BOTTOM MAY BE PROBLEM	-182 ha CULTIVATED -929 ha GRASSLAND AND BUSH -3 FARMSTEADS AND HUTTERITE COLONY TO BE RELOCATED

1) -EXISTING DIVERSION CAPACITIES AND 10% AND 30% DIVERSION GUIDELINES
2) -EXISTING DIVERSION CAPACITIES AND 60% DIVERSIONS GUIDELINES
3) -LITTLE BOW DIVERSION ENLARGED TO 5.66 m3/s WITH 60% DIVERSION GUIDELINE
4) -LITTLE BOW DIVERSION ENLARGED TO 8.5 m3/s WITH 60% DIVERSION GUIDELINE

DAMAGES ROADS AND UTILITIES	TOTAL PROJECT COST ($)	COST $/dam³ (acre feet) STORAGE	 WATER SUPPLY	REM
-SH 529 TO BE RELOCATED -TWO POWERLINES AND ONE TELEPHONE LINE AFFECTED	12,871,000 12,871,000 *12,871,000 *12,871,000	209 (258)	213 (263) 195 (241) *153 (189) *137 (169)	-FURTHEST DOWNSTR SUPPLY LEAST IRR -HIGHEST COST ALT -HIGHEST RESERVOI
-SH 529 TO BE RELOCATED -ONE POWERLINE AND ONE TELEPHONE LINE AFFECTED	10,947,000 10,947,000 *10,947,000 *10,947,000	219 (270)	192 (238) 172 (213) *168 (209) *124 (153)	-SMALLEST STORAGE PROVIDE LEAST BE -HIGHEST COST UNI
-SH 529 TO BE RELOCATED -ONE POWERLINE AND ONE TELEPHONE LINE AFFECTED	11,303,000 11,303,000 *11,303,000 *11,303,000	193 (238)	185 (231) 169 (211) *133 (167) *119 (149)	-FURTHEST UPSTREAM SUPPLY GREATEST -LEAST UNIT COST -LOWEST RESERVOIR

*PLUS COST OF DIVERSION CANAL EM

COST $/dam³ (acre feet)		REMARKS	RECOMMENDATIONS
STORAGE	WATER SUPPLY		
209 (258)	213 (263) 195 (241) *153 (189) *137 (169)	-FURTHEST DOWNSTREAM SITE, WOULD SUPPLY LEAST IRRIGATED AREA -HIGHEST COST ALTERNATIVE -HIGHEST RESERVOIR COSTS	DELETE
219 (270	182 (238) 172 (213) *168 (209) *124 (153)	-SMALLEST STORAGE CAPACITY, WOULD PROVIDE LEAST BENEFITS -HIGHEST COST/UNIT STORAGE	DELETE
183 (226)	185 (229) 169 (211) *135 (167) *119 (149)	-FURTHEST UPSTREAM SITE, WOULD SUPPLY GREATEST IRRIGATION AREA -LEAST UNIT COST ALTERNATIVE -LOWEST RESERVOIR COSTS	RETAIN FOR FURTHER STUDY

*PLUS COST OF DIVERSION CANAL ENLARGEMENTS

LIST OF REFERENCES

1. W-E-R Engineering Ltd., Little Bow River Basin Storage Site Investigation feasibility Design Report, June 1985

2. PFRA, Bow River Diversion to Oldman River Appendix B Diversion Works, April 1971

LIST OF APPENDICES

A - WATER SUPPLY AND HYDROLOGY
(Nanuk Engineering and Development Ltd.)

B - PRELIMINARY GEOLOGICAL/GEOTECHNICAL ASSESSMENT
(Thurber Consultants Ltd.)

C - PRELIMINARY COST ESTIMATE ANALYSIS

D - RESERVOIR DAMAGES AND LAND ACQUISITION

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONFLUENCE SITES
August, 1985

APPENDIX A

WATER SUPPLY AND HYDROLOGY

Box 817
Cochrane, Alberta T0L 0W0
Telephone (403) 932-3593

NANUK ENGINEERING & DEVELOPMENT LTD.

August 30, 1985

WER Engineering
Horizon 39 Building Box 2 Room 306
2735 39th Avenue NE
Calgary, Alberta
T1Y 4T8

Attention: Jack Wise

RE: LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION, CONFLUENCE SITES

Dear Jack;

A conceptual assessment of the hydrologic aspects of the three reservoir sites downstream of the confluence of Little Bow River and Mosquito Creek is complete and our report is hereby transmitted.

The hydrologic analyses included evaluation of the water supply provided by the reservoirs and the potential flood flows. The latter data is intended for comparative sizing and costing of flood protection components of the reservoirs only. Additional hydrologic work will be required for final design.

Yours truly,

PROFESSIONAL ENGINEER ALBERTA M. V. THOMPSON

M. V. Thompson, P.Eng.
Chief Engineer

MVT:lc
enclosure

PERMIT TO PRACTICE
NANUK ENGINEERING & DEVELOPMENT LTD.
Signature M V Thompson
Date Aug 30, 1985
PERMIT NUMBER: P 2906
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

1.0 WATER SUPPLY

The water supply available to each of the three confluence sites is the same, since all three sites receive runoff from Mosquito Creek and runoff on the main stem of the Little Bow is low or negligible. Total basin supply provided by the addition of a confluence reservoir was therefore the same for all three sites. Total basin supply is the volume of water available in the basin to meet water all requirements, primarily irrigation demand. The ratio of total basin supply to storage volume at various levels of reservoir capacity were calculated based on;

1. The water available for diversion from the Highwood River was calculated in accordance with two sets of guidelines;

    a. 10% of Highwood flow at Squaw Coulee and 30% of the Highwood flows at the Little Bow canal.

    b. A total of 60% of the Highwood flow through both diversion canals with a minimum flow of 70 cfs downstream of the Little Bow diversion

2. The physical capacity of the Squaw Coulee diversion was set at 60 cfs;

3. The capacity of the Little Bow diversion canal was varied from 100 to 300 cfs in 100 cfs increments;

4. The diversion canals were assumed to operate from April 15 to October 15 to provide water for irrigation and to the reservoir;

5. The municipal and riparian flow requirement of 15 cfs will be satisfied during the winter by diversion through the Litle Bow Canal;

6. Natural flows were calculated on an annual basis and were assumed to enter the reservoir in April of each year;

7. The draft from the reservoir and Highwood diversions served a variable irrigation demand and a uniform municipal, instream use and residual flow requirement;

8. The seasonal irrigation demand was distributed in accordance with the measured 1984 withdrawals as follows:

May	8%
June	30%
July	38%
August	19%
September	5%

9. Evaporative losses were calculated based on net evaporation at Calgary with a transfer factor of 1.0.

10. Water demands were distributed upstream and downstream of all sites as follows;

a. Mosquito Creek - 12%
b. Upper Little Bow - 20%
c. Lower Little Bow - 68%

11. Natural flows were calculated in the same manner as detailed in W.E.R. Engineering's report 'Little Bow River Basin, Storage Site Investigation'. The natural runoff in unit area terms are presented in Table 1.

1.1 METHODOLOGY

The method of evaluation used to critical period 1923 to 1938 to calculate the water balance in the reservoir. The initial part of this period was used to check that the reservoir could be filled by the fall of 1928. The latter part represents the most critical drought within the period of record.

The diversions to the Little Bow Basin from the Highwood River were made in such a manner as to satisfy irrigation demand upstream of the confluence sites.

The total basin supply afforded by a 50,000 ac.-ft confluence site was analysed for canal capacities varying from 100 to 500 cfs in 100 cfs increments. The latest diversion guideline of 60% of the Highwood flow with a minimum residual flow in the Highwood of 70 cfs was used in the analysis.

TABLE 1

NATURAL RUNOFF
(ac.ft./sq.mi/year)

YEAR	MOSQUITO CREEK	LITTLE BOW
1916	224	0
1917	263	0
1918	24	2
1919	8	12
1920	132	85
1921	14	15
1922	39	0
1923	144	2
1924	39	3
1925	51	12
1926	93	8
1927	225	31
1928	110	85
1929	114	8
1930	51	9
1931	0	12
1932	76	4
1933	55	13
1934	29	16
1935	21	9
1936	5	31
1937	7	7
1938	81	5
1939	25	12
1940	33	10
1941	16	12
	---	---
MEAN	72	16
	===	===

1.2 RESULTS

The results are presented in two parts. The variation of total basin supply or yield with storage capacity is presented for the following scenarios:

A. Figure 1: 30% & 10% guideline, Little Bow Canal @ 100 cfs.

B. Figure 2: 60% & 70 cfs min. guideline, Little Bow Canal @ 100 cfs

C. Figure 3: 60% & 70 cfs min. guideline, Little Bow Canal @ 200 cfs

D. Figure 4: 60% & 70 cfs min. guideline, Little Bow Canal @ 300 cfs

The hydrologic optimum reservoir size and corresponding total basin supply for each of the above scenarios are;

Scenario A - approximately 18,000 ac-ft and 38,000 ac-ft yield.

Scenario B - approximately 20,000 ac-ft and 42,000 ac-ft yield.

Scenario C - approximately 26,000 ac-ft and 55,000 ac-ft yield.

Scenario D - approximately 33,000 ac-ft and 65,000 ac-ft yield.

The second set of results pertain to a 50,000 ac-ft reservoir in either of the confluence sites. Figure 5 displays the basin yield versus the capacity of the Little Bow canal. The graph shows a 14,500 ac-ft increase in yield by increasing the canal capacity from 100 to 200 cfs. The next increase to 300 cfs produces an 7,800 ac-ft increase.

2.0 FLOODS

The flood hydrology from all three confluence sites was considered to be the same. The probable maximum flood (PMF) was determined using the SNBB method for prairie streams. The 1 in 25 and 1 in 100 year floods and associated by hydrographs were based on frequency analysis of the recorded maximum mean daily flows of the Little Bow River at Carmangay. The peak instantaneous flows were calculated from the maximum near daily flow using a historic ratio for recorded flood events.

The estimated values of the flood flows are listed below:

Estimates of Flood Flows

Drainage Area	PMF Max Daily	100 year Peak Instantaneous	25 year Instantaneous
(MI2)	(cfs)	(cfs)	
455	20,000-25,000	5,200	3,000

The 1:25 and 1:100 year flows are considerably less than those previously estimated for Mosquito Creek, Site 4. The probable reasons for this difference are:

1. Mosquito Creek makes a major contribution to flood flows in the Little Bow below the confluence. Floods in Squaw Coulee, Nanton Creek and the upper Little Bow are relatively small. The combined flood flow, when routed, will produce a lesser peak than estimated for Mosquito Creek Site 4 due to attenuation, but the volume of the flood flow is increased.

2. Mosquito Creek flood flows are overestimated as a result of transposition from Willow Creek.

CONFLUENCE SITE : LITTLE BOW RIVER

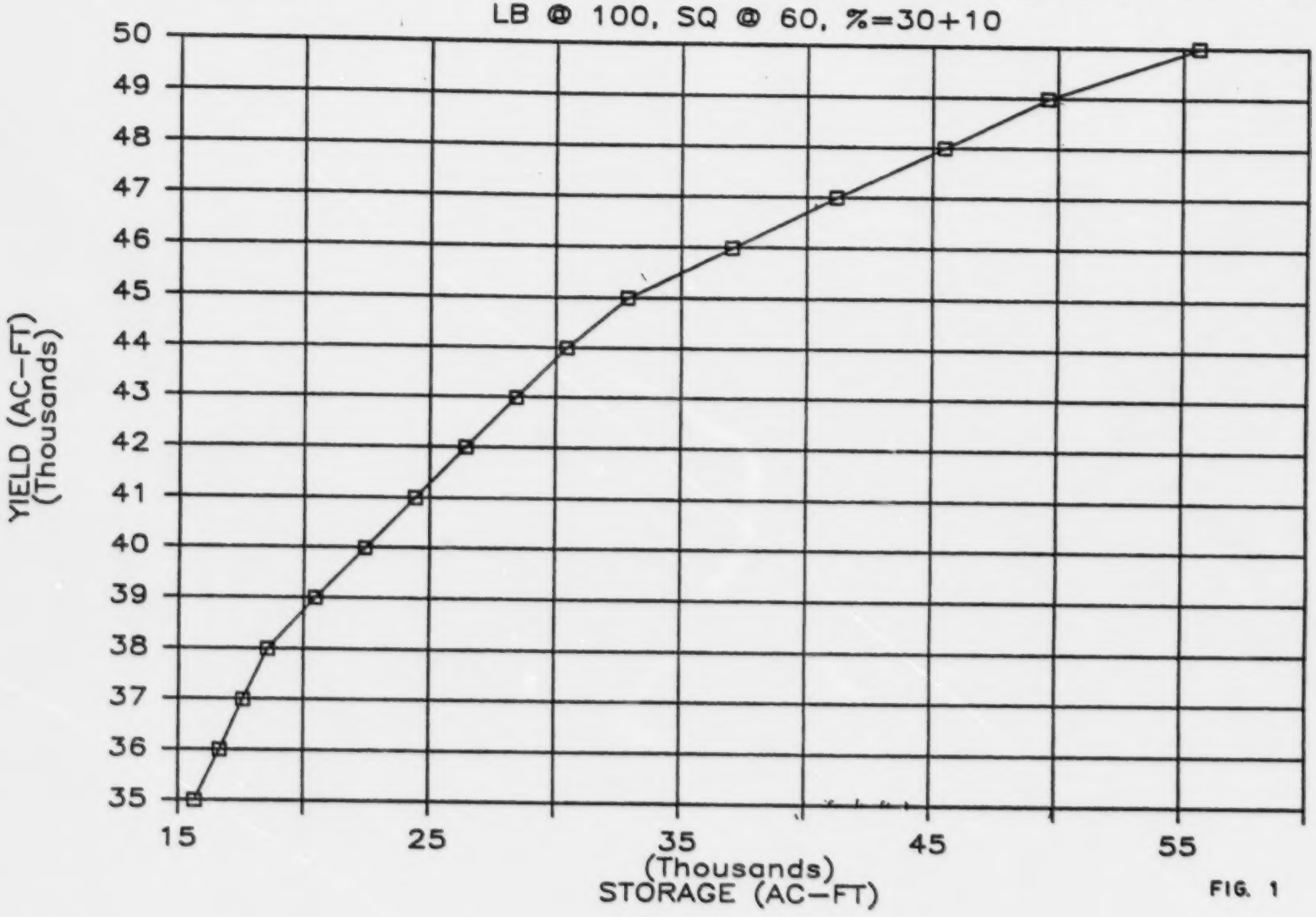


FIG. 1

CONFLUENCE SITE : LITTLE BOW RIVER

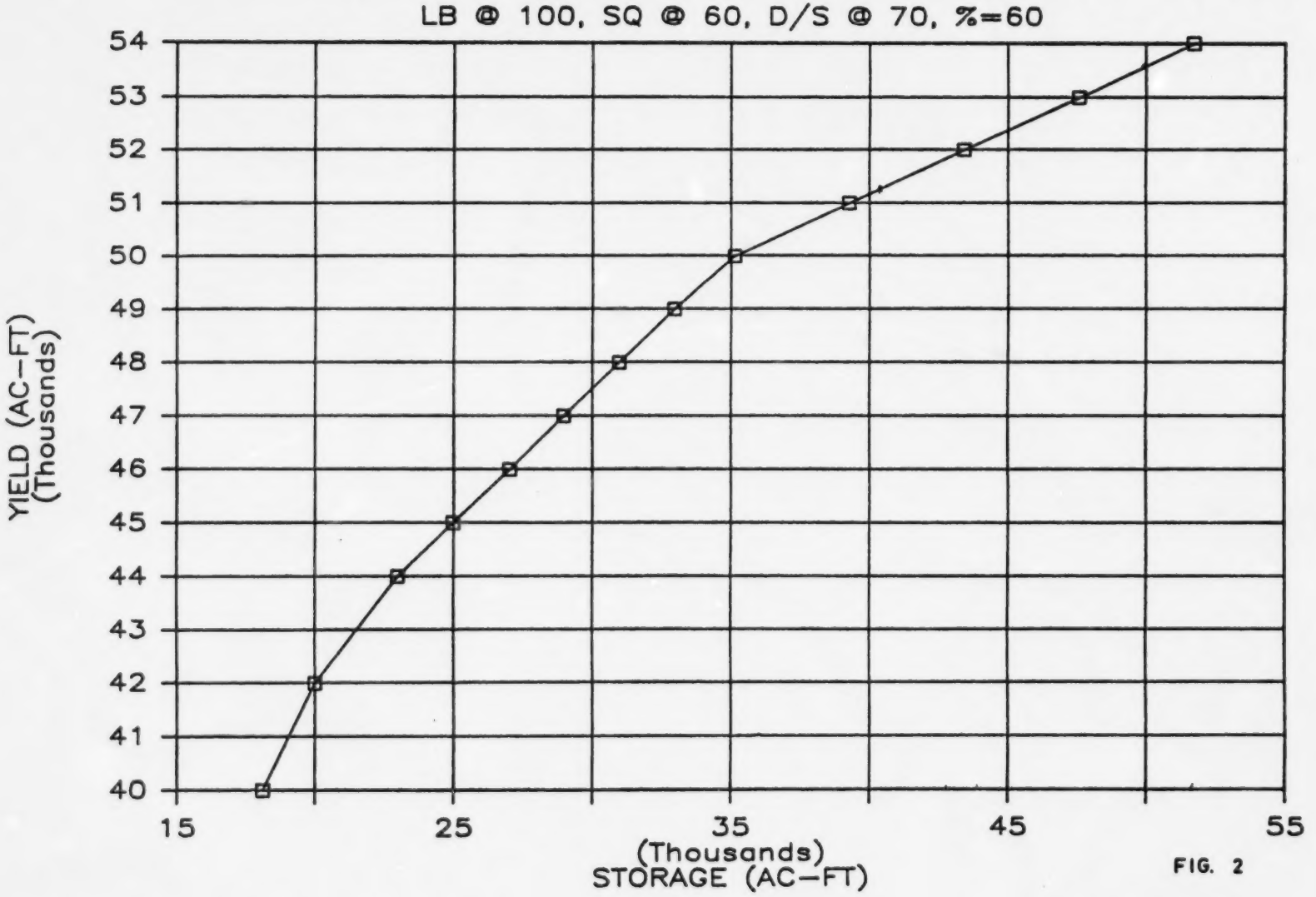


FIG. 2

CONFLUENCE SITE : LITTLE BOW RIVER

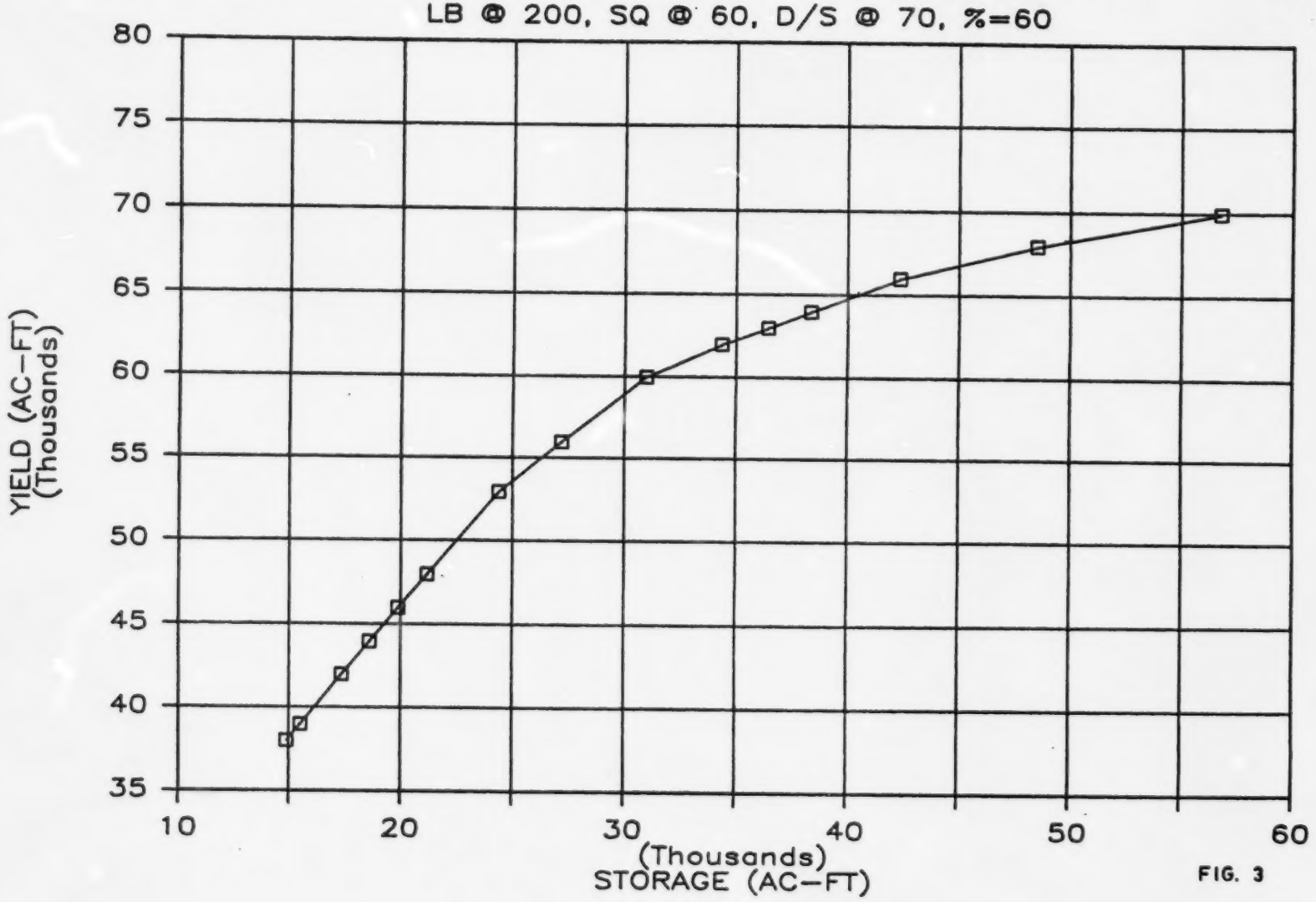


FIG. 3

CONFLUENCE SITE : LITTLE BOW RIVER

LB @ 300, SQ @ 60, D/S @ 70, %=60

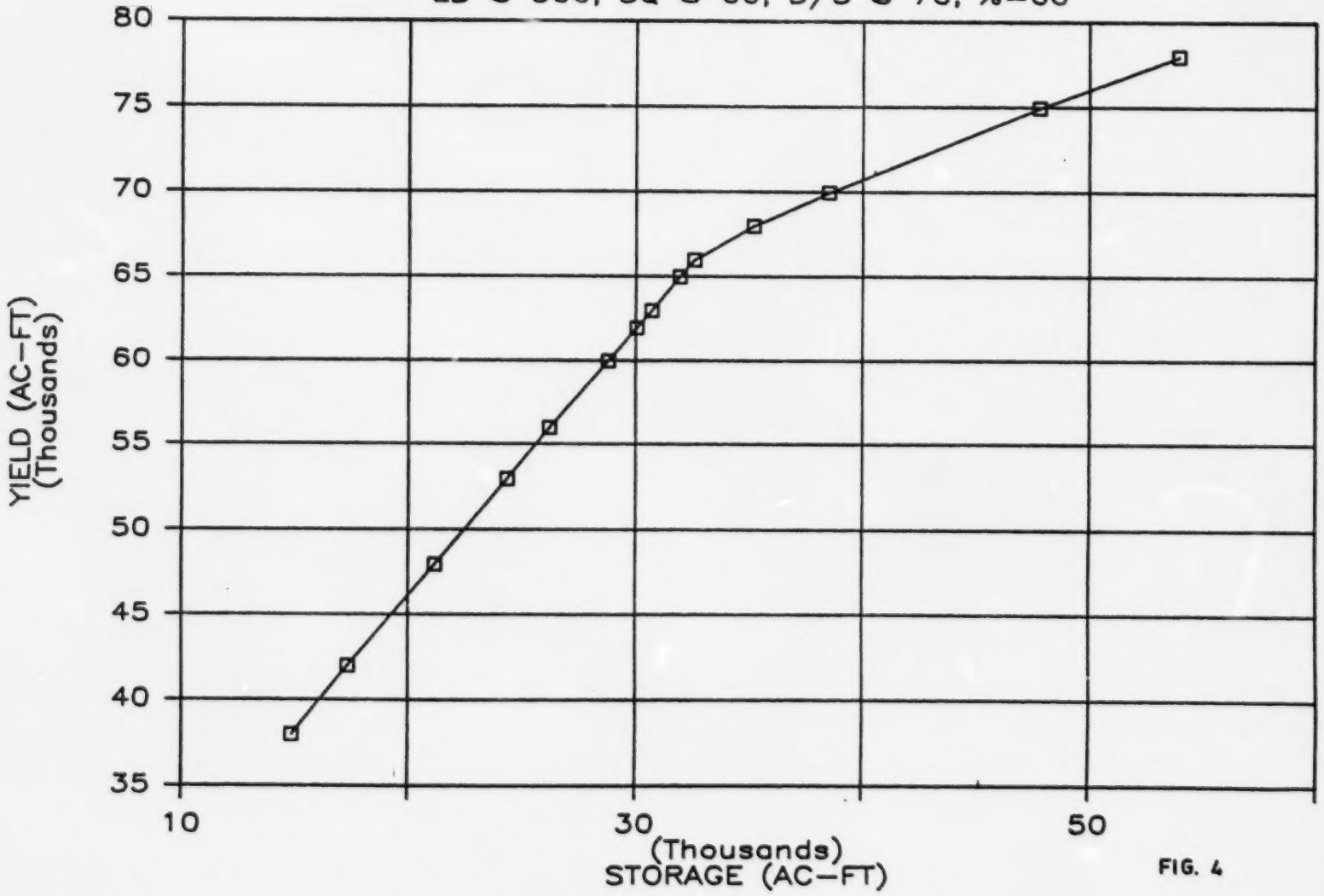


FIG. 4

CONFLUENCE SITE : LITTLE BOW RIVER

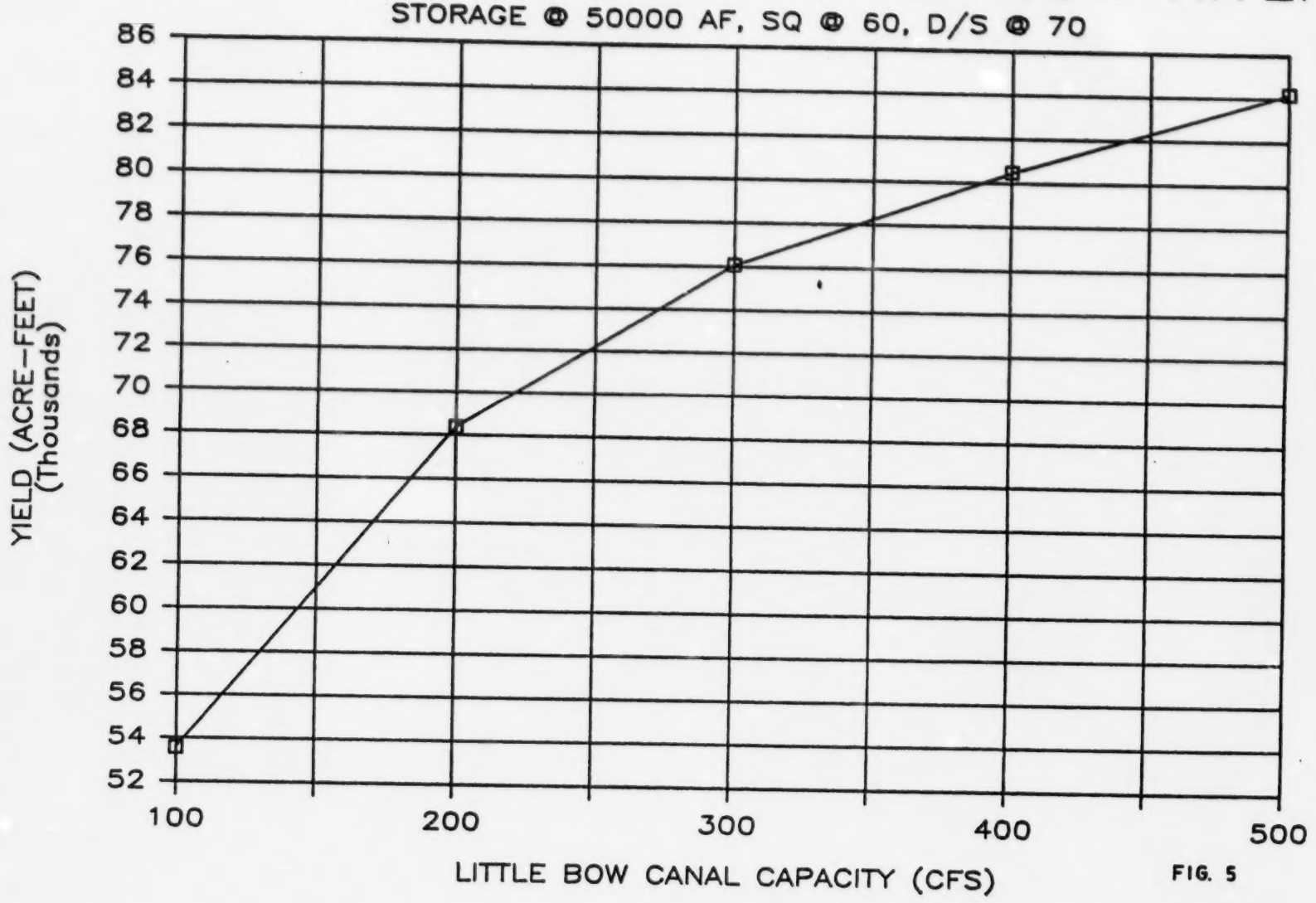


FIG. 5

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONFLUENCE SITES
August, 1985

APPENDIX B

PRELIMINARY GEOLOGICAL AND GEOTECHNICAL ASSESSMENT

LITTLE BOW RIVER BASIN STUDY
PRELIMINARY GEOLOGICAL AND GEOTECHNICAL ASSESSMENT
CONFLUENCE SITES

Submitted

to

W.E.R. ENGINEERING LTD.

Thurber Consultants Ltd.
Calgary, Alberta

G.C. Morgan, P.Eng.
Review Engineer

L.B. Smith, P.Eng.
Project Manager

I.G. Jones, M.Sc. Geol.
Project Engineer

PERMIT TO PRACTICE
THURBER CONSULTANTS LTD.
Signature
Date 30 July 85
PERMIT NUMBER: P 355
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

PROFESSIONAL GEOLOGIST I. JONES ALBERTA

July, 1985
File: 19-293-1

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
1.1	Scope of Study	1
1.2	Terms of Reference	2
2.0	REGIONAL GEOLOGICAL SETTING	3
2.1	Physiography, Relief and Topography	3
2.2	Bedrock Geology	3
2.3	Surficial Geology	4
2.4	Surface Drainage and Groundwater	4
3.0	IMPLICATIONS OF REGIONAL GEOLOGY FOR DAM AND RESERVOIR CONSTRUCTION	6
3.1	Bedrock Geology	6
3.2	Buried (Pre-Glacial) Valleys	6
3.3	Meltwater Channels and Spillways	7
3.4	Surficial Geology	7
4.0	DAM AND RESERVOIR SITES	8
4.1	Little Bow River Site 7B-1	8
4.2	Little Bow River Site 7B	8
4.3	Little Bow River Site 7A	9
APPENDIX A	Geotechnical Assessments for Proposed Dam and Reservoir Sites	
APPENDIX B	Drawing	

2266A

SECTION 1

INTRODUCTION

Thurber Consultants Ltd. have been retained by W.E.R. Engineering Ltd. to provide geological and geotechnical input to an assessment of possible dam/reservoir sites in the Little Bow River drainage basin. This report is concerned with three sites, designated Little Bow River sites 7A, 7B and 7B-1, located in the vicinity of the Mosquito Creek-Little Bow River confluence. Authorization to proceed with the investigation was received from Mr. J.M. Wise, P.Eng., of W.E.R. Engineering Ltd.

This report presents the results of the first phase of the geological and geotechnical assessment. Dam and reservoir characteristics have been determined and assessed, based on a review of available published and unpublished information and interpretation of high and low-level airphoto coverage. Preliminary evaluations for the Little Bow River sites 7A and 7B were presented previously, in a report dated March, 1985 (Our File: 19-293-0).

The following sections outline the scope of the study and detail the terms of reference.

1.1 Scope of Study

Water shortages in the Little Bow River basin and in southern Alberta have become increasingly apparent of late. This has prompted Alberta Environment to initiate studies of possible dam site/reservoir locations, development of which would permit storage within the basin to be increased. Nine potential sites (including Little Bow River sites 7A and 7B) were identified and assessed previously in the Little Bow River and Mosquito Creek valleys and Squaw Coulee. As an extension to the study, a requirement has now been identified to re-evaluate the "confluence" site, Little Bow River 7B-1, investigated in detail by PFRA in the early 1970's. A comparison with Little Bow River sites 7A and 7B is also required.

The overall objectives of the present study are to investigate conditions at each of the three "confluence" sites (Phase I). It is intended that, on this basis, a preferred location will be selected that warrants detailed, site-specific study leading to design and, possibly, construction (Phase II).

1.2 Terms of Reference

Detailed Phase I terms of references were established during discussions with W.E.R. Engineering Ltd., as follows:

a) Review available published and unpublished (PFRA, Alberta Environment and W.E.R. Engineering) geological and geotechnical data on the confluence area.

b) Carry out an interpretation of high and low-level airphoto coverage, to assess the regional geological setting and its implications for dam/reservoir construction, and investigate conditions at each site in detail.

c) Prepare an interim report which:

- describes the regional geology and its implications for dam siting and construction,
- discusses the geotechnical aspects of each dam and reservoir site, and
- provides recommendations as to a preferred site from the geotechnical viewpoint.

The following sections present the results of the study.

SECTION 2

REGIONAL GEOLOGICAL SETTING

The following sections describe regional geological conditions, based on the results of the literature review and airphoto interpretation studies. Implications of these conditions for dam and reservoir construction are addressed in Section 3.

2.1 Physiography, Relief and Topography

The study area is situated, within the Alberta Plain physiographic division of the Interior Plains, some 20 to 25 km southeast of Parkland, Alberta (Drawing 1, Appendix B). The Little Bow River reach of interest (including the three damsites and their potential reservoirs) is some 18 km long.

As shown on Drawing 1, the terrain within the area generally slopes gently from west to east. Elevations average about 950 m above sea level (asl). Superimposed onto the gently sloping plain is a series of ice-marginal meltwater channels. These generally trend northwest-southeast and are incised to depths of 15 m to 30 m below the general prairie level within the study area.

In the vicinity of the Little Bow River valley, relief is generally gently undulating to rolling, with local areas of subdued hummocky terrain. While slopes of less than 15 degrees are characteristic, slopes in excess of 50 degrees exist along the walls of the various meltwater channels. A short distance to the west, around Clear Lake, areas of ridged to hummocky terrain are present, developed on glaciofluvial esker and kame deposits.

2.2 Bedrock Geology

Although Green (1982) indicates that Upper Cretaceous Horseshoe Canyon Formation bedrock underlies the confluence area, previous drilling results at the Little Bow River 7B-1 site suggest that the overlying Willow Creek Formation, of Upper Cretaceous to Tertiary age, is the uppermost bedrock unit within the study area. This formation, a lateral stratigraphic equivalent of the Paskapoo Formation, comprises an interbedded sequence of non-marine shales and siltstones, with some medium to coarse-grained sandstones. Minor constituents are bentonitic shale and bentonite.

The bedrock is usually masked by younger Pleistocene and Holocene sediments. Locally, it is exposed, or present beneath a shallow colluvial veneer, along the walls of the various meltwater channels.

The bedrock surface was subjected to subaerial erosion in preglacial times and was dissected by an extensive network of river and stream valleys. These valleys are now buried, having been infilled by a complex series of preglacial, glacial and post glacial deposits.

2.3 Surficial Geology

Surficial deposits, of both glacial and post-glacial origin are present in the vicinity of the Little Bow River-Mosquito Creek confluence

Glacial till, forming ground moraine, is the dominant surficial material. It comprises a heterogeneous mixture of clay to gravel size material, deposited by Laurentide ice as it traversed the area (ground moraine) or from ice that decayed in place (hummocky moraine). Glaciofluvial deposits, sands and gravels predominantly, deposited by meltwater, are also locally abundant, notably in the Clear Lake area to the west of the Little Bow River valley, where they form esker, delta and kame deposits. On the uplands adjacent to the river valley, sands and silts of glaciolacustrine (glacial lake) origin frequently form a veneer over the morainal deposits.

Since deglaciation, post-glacial erosional and depositional processes have led to the development of a variety of more recent deposits. Alluvial and colluvial materials are most important, respectively forming floodplain and terrace, and slopewash deposits along the floors and walls of the various meltwater channels. Recent lake deposits and organics have accumulated locally in terrain depressions.

The thickness of the surficial deposits overlying the bedrock averages in the order of 10 m over much of the study area. Within the buried pre-glacial Tee Pee Valley, however, thicker surficial deposits may exist.

2.4 Surface Drainage and Groundwater

The area of interest is drained by a series of generally northwest to southeast trending streams, of which the Little Bow River and Mosquito Creek are amongst the most

important. Surface drainage and run-off is generally into these water courses, but also locally into closed depressions whence it either evaporates or seeps into the ground.

Three groundwater flow regimes, one superimposed on the other, are identified. On a "regional" scale, groundwater flows at depth, from recharge areas in the Foothills and Rockies to discharge further east in the Plains. On a smaller scale, "local" groundwater flows are recharged in the higher sections of the area and discharge into the river and creek valleys. Finally, "perched" flows exist within granular, and more permeable, overburden zones and at the overburden-bedrock contact. These latter discharge into terrain depressions, as well as the river and creek valleys.

SECTION 3

IMPLICATIONS OF REGIONAL GEOLOGY FOR DAM AND RESERVOIR CONSTRUCTION

Geological conditions impact upon, and have implication for, dam and reservoir construction in four main respects.

3.1 Bedrock Geology

The Willow Creek Formation is the uppermost bedrock unit in the confluence area. According to Green (1982), however, Horseshoe Canyon Formation strata may be present locally. Bedrock appears to outcrop in the vicinity of all three sites.

Generally favourable construction conditions are indicated since, like the Paskapoo Formation occuring at potential dam sites further west, the Willow Creek strata are usually flat-lying and only moderately jointed and fractured. Further, bentonitic horizons are only sporadically distributed and slopes are relatively stable. A number of large landslides were identified during the regional airphoto study, mostly downstream of the possible dam site locations (and, thus, perhaps in areas where Horseshoe Canyon bedrock outcrops). Landslides are also present in the Mosquito Creek valley, upstream of the presently-considered reservoir limits. Constraints relative to seepage through joints and fractures and spillway excavation and abutment preparation in bedrock (especially where massive sandstone strata may exist) are also identified.

3.2 Buried (Pre-Glacial) Valleys

In pre-glacial times, an extensive network of river and stream valleys was developed in this part of Alberta. These were cut down into bedrock and have subsequently been infilled by a thick overburden sequence that may include a thick basal sand and gravel unit. Within the area of interest, the Tee Pee Valley, the thalweg for which is indicated on Drawing 1, is most important. It is inferred to be followed by the Little Bow River valley throughout the reach of interest, with a tributary joining it from the west a short distance downstream from the 7B site (Drawing 1).

Buried valleys are a concern insofar as they may have a negative impact on reservoir watertightness. In addition, they may be a source of high groundwater pressures beneath the dam. It may be noted, however, that the northern part of the Travers Reservoir is located over such a buried valley (Tee Pee Valley), apparently without serious problems to date.

3.3 Meltwater Channels and Spillways

As indicated on Drawing 1, the area of interest is traversed by a series of northwest-southeast trending meltwater channels. These steep-sided and relatively deeply-incised channels are abandoned ice-marginal spillways, of early post-glacial age.

The channels form prime locations for dam and reservoir siting. From a geotechnical viewpoint, however, the characteristics of the valley infill deposits (in terms of porosity/permeability, composition and compressibility) may be of concern.

3.4 Surficial Geology

In general, the distribution of surficial deposits, detailed in Section 2.3, is favourable for dam and reservoir construction. The surficial glacial tills will provide a source of good quality clay fill material, while random granular fill may be obtained from glaciofluvial kames and eskers and alluvial floodplains and terraces. Detailed field testing, by means of drilling or test pitting, will be required prior to borrow pit development. The PFRA study of Site 7B-1 suggests that select granular material may be available from commercial operations in the area.

Based on the airphoto study, sources of rip-rap (other than fieldstone piles) were not identified. It is possible that further, detailed, studies will locate sources. However, at this time, it should be anticipated that rip-rap will have to be imported.

SECTION 4

DAM AND RESERVOIR SITES

Geological characteristics of the three confluence dam and reservoir sites are described below. Geotechnical concerns identified at each location are also indicated. Tables providing summaries of these data are attached, in Appendix A.

4.1 Little Bow River Site 7B-1

At this site, the Little Bow River occupies a "U"-shaped valley, some 1050 m wide (crest-to-crest) and approximately 27 m deep. A 600 m wide high-level terrace is present, about 10 m below prairie level, on the west side.

On the east abutment, the valley is cut down, through nearly 20 m of glaciolacustrine sands, silts and clays and glacial till, into bedrock. Conditions within the terrace on the west abutment are more complex, comprising a sequence of alluvial sand and gravel, overlying glacial till, overlying inter-glacial (or preglacial) sands, silts and clays. Bedrock occurs at or just below river level. The stratigraphic sequence strongly suggests that the buried Tee Pee Valley is located below the west abutment of this site.

A clay core (or similar) cut-off may be required at this site to control seepage through the valley bottom and west abutment (upper) alluvium. Preliminary design side-slopes of 4H:1V upstream and 3H:1V downstream are recommended. Geotechnical concerns are identified from a slope stability point of view, relative to the presence of pre-existing failure planes within the interglacial (lower) alluvium on the west abutment, and the potential for settlement of the upper alluvium. For the latter reason, location of structures on the west side is not recommended.

4.2 Little Bow River Site 7B

This site occupies a narrow but relatively deep "U"-shaped valley some 400 m wide and 15 to 20 m deep.

The valley is apparently cut down into till; bedrock likely occurs at or below river level. The valley infill deposits are inferred to be quite shallow. Reservoir watertightness is not anticipated to be a concern.

Seepage through the valley bottom alluvium is identified as a possible concern, likely requiring construction of a clay core (or similar) cut-off. For purposes of preliminary design, dam sideslopes of 4H:1V upstream and 3H:1V downstream are recommended.

The thalweg of the buried Tee Pee Valley passes close to the Little Bow River Site 7-B. In the event it is present within the proposed dam site, some or all of the geotechnical concerns identified at Site 7B-1 may apply.

4.3 Little Bow River Site 7A

The Little Bow River valley at Site 7A is "U"-shaped, relatively broad (approximately 600 to 700 m, crest-to-crest) and 15 to 20 m deep.

The valley is apparently cut down into glacial till; bedrock was not observed in the field and is inferred to exist close to or below river level. An abandoned, high-level, channel exists on the north abutment. A buried tributary joins the preglacial Tee Pee Valley a short distance upstream of Site 7A but is not anticipated to be a concern from the reservoir water tightness point of view.

The abandoned channel is, however, cause for some concern and may require dyking. In addition, a clay core (or similar) cut-off may be required to control seepage through the valley bottom alluvium. Dam sideslopes of 4H:1V upstream and 3H:1V downstream are proposed for preliminary design purposes.

The buried Tee Pee Valley thalweg is believed to pass close to Site 7-A. If it exists within the proposed dam site, some or all the concerns at Site 7B-1 may apply.

APPENDIX A

GEOTECHNICAL ASSESSMENTS FOR PROPOSED DAM AND RESERVOIR SITES

SITE:	Little Bow River 7B-1
DAMSITE LOCATION Sec-Twp-Rge (W4M):	8-15-25
GEOLOGICAL SETTING:	- "U"-shaped valley; 1050 m wide (crest-to-crest), including 600 m wide high-level terrace, and 27 m deep. - Relatively shallow valley infill.
DAM SITE:	- Glacial till, with glaciolacustrine sand veneer, over bedrock at about midslope, on east abutment. - Predominantly granular valley infill. - Buried Tee Pee Valley passes below west abutment. Complex stratigraphy consisting of sand and gravel alluvium, over glacial till, over interglacial sand, silt and clay, with bedrock close to river level.
RESERVOIR:	- No major problems identified.
BORROW SOURCES:	- Common fill from abutments. - Random granular from floodplain, terraces and kames and eskers in area. - Likely requirement to import select granular (from local pits) and rip-rap.
ENGINEERING CONCERNS:	- Clay core cut-off likely required to control seepage through valley bottom and west abutment upper terrace alluvium. - Occurence of pre-existing failure planes or slickensides within interglacial alluvium below west abutment. - Potential for settlement of upper terrace alluvium below west abutment. - Seepage through pre-glacial valley deposits must be investigated further.

PRELIMINARY DESIGN RECOMMENDATIONS:

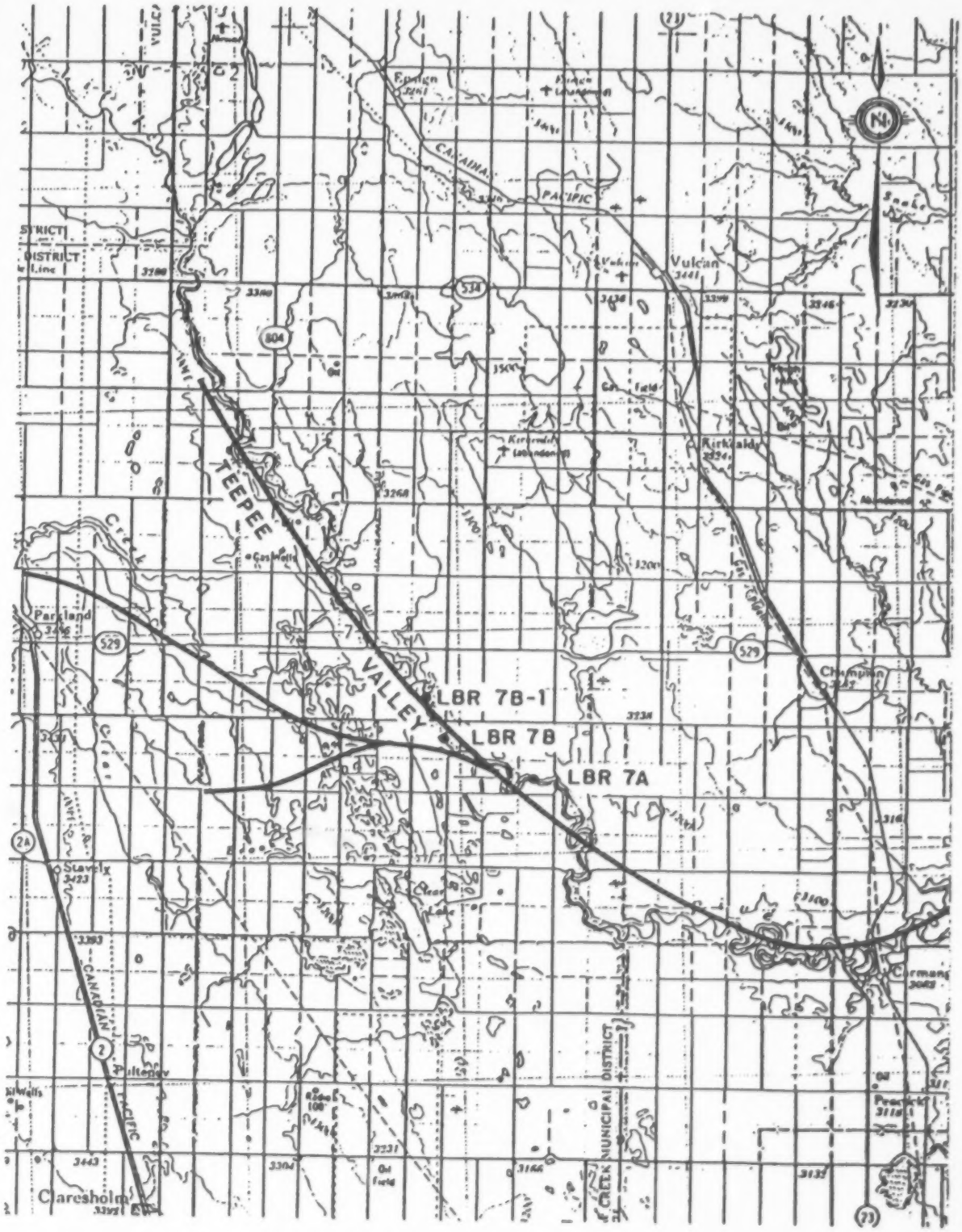
- Dam sideslopes of 4H:1V upstream and 3H:1V downstream.
- Requirement for valley bottom and west abutment clay core cut-off.
- Slope protection to consist of rip-rap over random granular.

SITE:	Little Bow River 7B
DAMSITE LOCATION Sec-Twp-Rge (W4M):	31/32-14-25
GEOLOGICAL SETTING:	- "U"-shaped valley; 400 m wide and about 15 to 20 m deep. - Relatively shallow valley infill.
DAM SITE:	- Glacial till on both abutments, with glaciolacustrine veneer. - Bedrock likely close to river level. - Valley infill predominantly granular. - Possible presence of buried valley makes assessment of probable stratigraphic sequence unreliable at this site.
RESERVOIR:	- No major problems identified.
BORROW SOURCES:	- Common fill from abutments and spillway excavation. - Random granular from floodplain, terraces and kames and eskers in area. - Likely requirement to import select granular (from local pits) and rip-rap.
ENGINEERING CONCERNS:	- Seepage through valley bottom alluvium. - Possible presence of buried valley below dam site.
PRELIMINARY DESIGN RECOMMENDATIONS:	- Dam sideslopes of 4H:1V upstream and 3H:1V downstream. - Requirement for clay core cut-off to control valley bottom seepage. - Slope protection to consist of rip-rap over random granular.

SITE:		Little Bow River 7A
DAMSITE LOCATION Sec-Twp-Rge (W4M):		27-14-25
GEOLOGICAL SETTING:	-	"U"-shaped valley; some 600-700 m wide and 15 m deep; relatively shallow valley infill; high-level channel on north abutment.
DAM SITE:	-	Glacial till on both abutments, bedrock at or below river level.
	-	Glaciolacustrine veneer.
	-	Granular alluvial deposits in valley bottom.
	-	Possible presence of buried valley makes assessment of probable stratigraphic sequence unreliable at this site.
RESERVOIR:	-	Abandoned channel on north abutment must be dyked.
BORROW SOURCES:	-	Common fill from abutments and spillway excavation.
	-	Random granular from floodplain, and eskers and kames and existing pits.
	-	May be need to import select granular (from local pits) and rip-rap.
ENGINEERING CONCERNS:	-	Abandoned high-level channel on north abutment may require dyke.
	-	Clay core cut-off required to control seepage through valley bottom alluvium.
	-	Embankment settlement unlikely of concern.
	-	Possible presence of buried valley below dam site.
PRELIMINARY DESIGN RECOMMENDATIONS:	-	Dam sideslopes of 4H:1V upstream 3H:1V downstream.

APPENDIX B

DRAWING



W-E-R ENGINEERING LTD.

IGJ/JAB

FILE NO. 19-293-1

DATE JULY 1983

APPROVED Howes

SCALE 1:250,000

DRAWING NO 1/

LOCATION PLAN
PROPOSED CONFLUENCE DAM SITES
LITTLE BOW RIVER BASIN

THURBER CONSULTANTS LTD., Geotechnical Engineers

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONFLUENCE SITES
August, 1985

APPENDIX C

PRELIMINARY COST ESTIMATE ANALYSIS

TABLE C1
LITTLE BOW SITE 7A
Preliminary Cost Estimate

	Quantity	Unit Price	Extension
Care of Water	lump sum		275,000
SUBTOTAL			275,000
Embankment			
Foundation preparation & Core Trench Excavation	49,260 m^3	3.00	148,000
Borrow Area Excavation & Haul - Impervious	672,200 m^3	2.00	1,344,000
Compacted Embankment	604,200 m^3	0.90	544,000
Embankment Filter & Drainage System	12,220 m^3	21.00	257,000
Rock Riprap	21,800 m^3	35.00	763,000
Granular Blanket, Below Riprap	18,760 m^3	16.00	300,000
Miscellaneous Items	lump sum		336,000
SUBTOTAL EMBANKMENT			3,692,000
Spillway			
Excavation and Haul	83,400 m^3	2.60	217,000
Reinforced Concrete	1,580 m^3	525.00	830,000
Drainage System	lump sum	25,000.00	25,000
Miscellaneous Items	lump sum		107,000
SUBTOTAL SPILLWAY			1,179,000
Diversion & Permanent Outlet Works			
Excavation	1,725 m^3	3.50	6,000
Reinforced Concrete	313 m^3	765.00	246.000
Precast Pipe	165 lin-m	1,250.00	206,000
Concrete Bedding	211 m^3	275.00	58,000
Control Gates & Hoists	2 gates	30,000.00	60,000
Miscellaneous Items	lump sum		58,000
SUBTOTAL DIVERSION & OUTLET WORKS			634,000
SUBTOTAL CONSTRUCTION			5,780,000
Contingencies (30%)			1,734,000
TOTAL CONSTRUCTION COST			7,514,000

TABLE C2
LITTLE BOW SITE-7B
Preliminary Cost Estimate

	Quantity	Unit Price	Extension
Care of Water	1 lump sum		227 000
SUBTOTAL			227 000
Embankment			
Foundation preparation & Core Trench Excavation	44 137 m^3	3.00	132 000
Borrow Area Excavation & Haul - Impervious	479 633 m^3	2.00	959 000
Compacted Embankment	444 270 m^3	0.90	400 000
Embankment Filter & Drainage System	8 810 m^3	21.00	185 000
Rock Riprap	17 920 m^3	35.00	627 000
Granular Blanket, Below Riprap	14 930 m^3	16.00	239 000
Miscellaneous Items	1 lump sum		254 000
SUBTOTAL EMBANKMENT			2 796,000
Spillway			
Excavation and Haul	64 068 m^3	2.60	167 000
Reinforced Concrete	1 650 m^3	525.00	866 000
Drainage System	1 lump sum	28 000.00	28 000
Miscellaneous Items	1 lump sum		106 000
SUBTOTAL SPILLWAY			1 167 000
Diversion & Permanent Outlet Works			
Excavation	5 958 m^3	3.50	21 000
Reinforced Concrete	282 m^3	785.00	221 000
Precast Pipe	140 lin-m	1 250.00	175 000
Concrete Bedding	166 m^3	275.00	46 000
Control Gates & Hoists	2 gates	30 000.00	60 000
Miscellaneous Items	1 lump sum		52 000
SUBTOTAL DIVERSION & OUTLET WORKS			575 000
SUBTOTAL CONSTRUCTION			4 765 000
Contingencies (30%)			1 430 000
TOTAL CONSTRUCTION COST			6 195 000

TABLE C3
LITTLE BOW SITE-7B-1
Preliminary Cost Estimate

	Quantity	Unit Price	Extension
Care of Water	1 lump sum		243 000
SUBTOTAL			243 000
Embankment			
Foundation preparation & Core Trench	45 130 m^3	3.00	135 000
Borrow Area Excavation & Haul	519 000 m^3	2.00	Excavation 1 038 000
Compacted Embankment	527 593 m^3	0.90	Impervious 475 000
Embankment Filter & Drainage System	9 770 m^3	21.00	205 000
Rock Riprap	19 150 m^3	35.00	670 000
Granular Blanket, Below Riprap	15 960 m^3	16.00	255 000
Miscellaneous Items	1 lump sum		278 000
SUBTOTAL EMBANKMENT			3 056 000
Spillway			
Excavation and Haul	132 150 m^3	2.60	344 000
Reinforced Concrete	1 380 m^3	525.00	725 000
Drainage System	1 lump sum	21 000.00	21 000
Miscellaneous Items	1 lump sum		109 000
SUBTOTAL SPILLWAY			1 199 000
Diversion & Permanent Outlet Works			
Excavation	3 400 m^3	3.50	12 000
Reinforced Concrete	292 m^3	785.00	229 000
Precast Pipe	150 lin-m	1 250.00	188 000
Concrete Bedding	188 m^3	275.00	52 000
Control Gates & Hoists	2 gates	30 000.00	60 000
Miscellaneous Items	1 lump sum		54 000
SUBTOTAL DIVERSION & OUTLET WORKS			595 000
SUBTOTAL CONSTRUCTION			5 093 000
Contingencies (30%)			1 528 000
TOTAL CONSTRUCTION COST			6 621 000

LITTLE BOW RIVER BASIN
STORAGE SITE INVESTIGATION
CONFLUENCE SITES
August 1985

APPENDIX D

RESERVOIR DAMAGES AND LAND ACQUISITION

1.0 Basis of Reservoir Costs

An estimate of the costs associated with land acquisition and reservoir damages has been prepared, as detailed in subsequent sections of this appendix. Location plans of reservoir damages are shown on Figures D1 through D3.

1.1 Land Acquisition

The areas of land required for each of the three resevoirs were based on top-of-dam elevation to allow for reservoir surcharge during river flood stages and for possible future erosion of the reservoir abutments. The total reservoir areas were broken down into cultivation (including hay flats) and other land use (pasture, bush, river) as based on field inspections and air photo studies in conjunction with topographic plans of the reservoir. Unit land costs of $1980 per hectare (ha) of cultivation and $740 per hectare of other lands as used in a previous report (Ref 1) have been discussed with officials from the Municipal District of Foothills and are considered to be representative of current land values in this area. An additional allowance of 25% for serverance and acquisition cost has been included.

1.2 Reservoir Damages

Damages associated with the reservoirs included in this phase of the study include the following:

- -roads and bridges
- -power transmission lines
- -telephone lines
- -natural gas lines
- -farm buildings

The costs associated with public utilities were estimated based on information supplied by Trans-Alta Utilities Corporation, Canadian Western Natural Gas Company Limited, and Alberta Government Telephones.

The costs associated with relocation of existing farm buildings effected by the reservoir were based generally on costs supplied by local moving companies in connection with a study of Keho Lake Enlargement (1980) updated to 1985.

The costs of raising existing roads and bridges were calculated separately for each road.

2.0 Little Bow Site 7A

2.1 Land Acquisition

The total area of land within the top-of-dam contour (962.2) is 1025 ha, of which 303 ha are cultivated or seeded to tame grasses. The cost of acquisition is estimated as follows:

Cultivation	303 ha @ $1980	=	$ 600,000
Other	722 ha @ $ 740	=	534,000
Severance (25%)		=	284,000
	TOTAL		$1,418,000

2.2 Reservoir Damages

2.2.1 Roads

a) SE 5-15-25-W4

This existing road and bridge would be flooded by the Site 7-A reservoir. Traffic can be re-routed on existing roads at no additonal cost.

b) Secondary Highway 529

This is a paved secondary highway which crosses the Site 7A reservoir at the north boundary of Sec 12-15-26-W4. Three alternatives were examined:

1) Raise the existing road and bridge by 6.3 metres at a cost estimated at $2.7 million

2) Relocate three kilometres north as shown in Figure D1 at a cost estimated at $1.6 milion. This alternative requires six additional kilometres of travel for traffic estimated at 200 vehicles per day, but is the most economical alternative.

3) Re-route six kilometres south of the present location at an estimated cost of $1.4 million. This alternative requires 13 additional kilometres of travel for S.H. 529 traffic, plus additional costs of $900,000 for re-routing an additonal gravel road

c) SE 26-15-26

An existing gravelled road crosses the Little Bow River via a pile-supported steel truss bridge. In this study it is assumed that the crossing would be upgraded to carry the additional traffic resulting from the rerouting of secondary highway 529 (as per section 2.2.1 b2, above).

2.2.2 Utilities

A three phase power line on double wooden poles crosses the Little Bow River along the east boundary of Section 31-14-25. Special long-span towers are proposed at the top of the valley, at an estimated cost of $200,000.

A small single phase power line crosses near the upper end of the reservoir in the SE 26-15-26. Cost of relocation is estimated at $25,000.

No pipelines were found to be effected by the reservoir with the exception of a natural gas service line to one set of farm buildings which are to be relocated.

The cost of re-connection of gas service is included in the building relocation cost.

One short section of telephone lines in the SW 18-15-25 would have to be relocated at an estimated cost of $5,000.

2.2.3 Farmsteads

a) NE 31-14-25

The relocation of these 6 occupied buildings including re-connection of utilities is estimated at $70,000.

b) NE 12-15-26

The relocation of this occupied farmstead is estimated at $80,000.

c) Hutterite Colony SE 13-15-26

The Little Bow River Hutterite Colony consists of a large number of buildings, some of which would have to be dismantled and re-constructed. The costs of dismantling and re-constructing the major buildings, plus relocation of the smaller structures, including re-connection of utilities are estimated at $800,000.

d) SE 26-15-26

Relocation of this occupied farmstead is estimated to cost $80,000.

Reservoir Cost Summary

Land Acquisition	$1,400,000
Roads and Bridges	1,600,000
Utilities	230,000
Farm Buildings	1,030,000
TOTAL	$4,230,000

3.0 LITTLE BOW SITE 7B

3.1 Land Acquisition

The total area of land within the top-of-dam elevation (965.0) is 1000 ha of which 266 ha are cultivated or seeded to tame grass.

The cost of acquisition is estimated as follows:

Cultivation	266 ha @ $1980	527,000
Other	734 ha @ $ 740	543,000
Severence (25%)		268,000
		$1 338 000

3.2 Reservoir Damages

3.2.1 Roads

a) S.H 529 North Boundary 12-15-26-W4

Three alternative road crossings for S.H 529 were examined in the study. The most economical was that of re-routing the road over the Site 7B dam, (as shown in Figure D2) and

upgrading existing roads to secondary highway standards. The additional length of S.H 529 would be six kilometres. This alternative requires a bridge across the spillway channel, and a bridge across Mosquito Creek. The cost is estimated to be $1.4 million.

b) SE 5-15-26, W-4 and SE 26-15-26-W4

Existing local traffic which crosses the Little Bow River at the above noted locations would be re-routed to S.H. 529, and the present crossings abandoned.

3.2.2 Utilities

A small single-phase line which crosses in the SE 26-15-26 would have to be relocated at an estimated cost of $50,000.

No pipelines effected by the reservoir have been identified in this study with the exception of a natural gas service line to some farm buildings which are to be relocated.

One short section of telephone lines is to be relocated at an estimated cost of $5,000.

3.2.3 Farmsteads

a) NE 31-14-25-W4

These occupied farm buildings, described in Section 2.2.3 (a) of this report would require relocation at an estimated cost of $70,000.

b) Ne 12-15-26-W4

The relocation of this occupied farmstead is estimated at $80,000.

c) Hutterite Colony Se 13-15-26-W4

The Little Bow River Hutterite Colony, described earlier in this report would be flooded by the reservoir. The costs of dismantling and re-assembling the larger buildings, plus many of the smaller buildings is estimated at $800,000.

d) SE 26-15-26-W4

These occupied buildings would have to be relocated at an estimated cost of $80,000.

Reservoir Cost Summary

Land Acquisition		$1,338,000
Roads		1,400,000
Utilities		55,000
Farm Buildings		1,030,000
	TOTAL	$3,823,000

4.0 LITTLE BOW SITE 78-1

4.1 Land Acquisition

The total area of land affected by the reservoir to top-of-dam elevation is 1110 ha, of which 182 ha are cultivated as tame hay flats. The costs of acquisition are estimated as follows:

Cultivation	182 ha @ $1980	$ 360,000
Other	928 ha @ $ 740	687,000
	Serverance (25%)	262,000
	TOTAL	$1,309,000

4.2 Reservoir Damages

4.2.1 Roads

a) S.H 529

Three alternative routes for S.H. 529 were considered, of which the most economical by a wide margin involves relocating three kilometres south as shown in Figure D3 at an estimated cost of $1.3 million. This would increase the present length of S.H. 529 by six kilometres.

b) SE 26-15-26

The existing bridge on this road would be abandoned, and local traffic re-routed over S.H. 529.

4.2.2 Utilities

A small single-phase power line described in Section 2.2.2 would be re-routed at an estimated cost of $65,000.

No pipelines were found to be effected by the reservoir.

One short section of telephone lines would be relocated at a cost of $5,000.

4.2.3 Farmsteads

a) NE 5-15-25-W4

These buildings, although above the reservoir level could be effected by the spillway for Site 7B-1. Relocation costs are estimated at $50,000.

b) NE 12-15-26-W4

The cost of relocation of these buildings, described in previous sections of this report are estimated at $80,000.

c) SE 13-15-26-S4

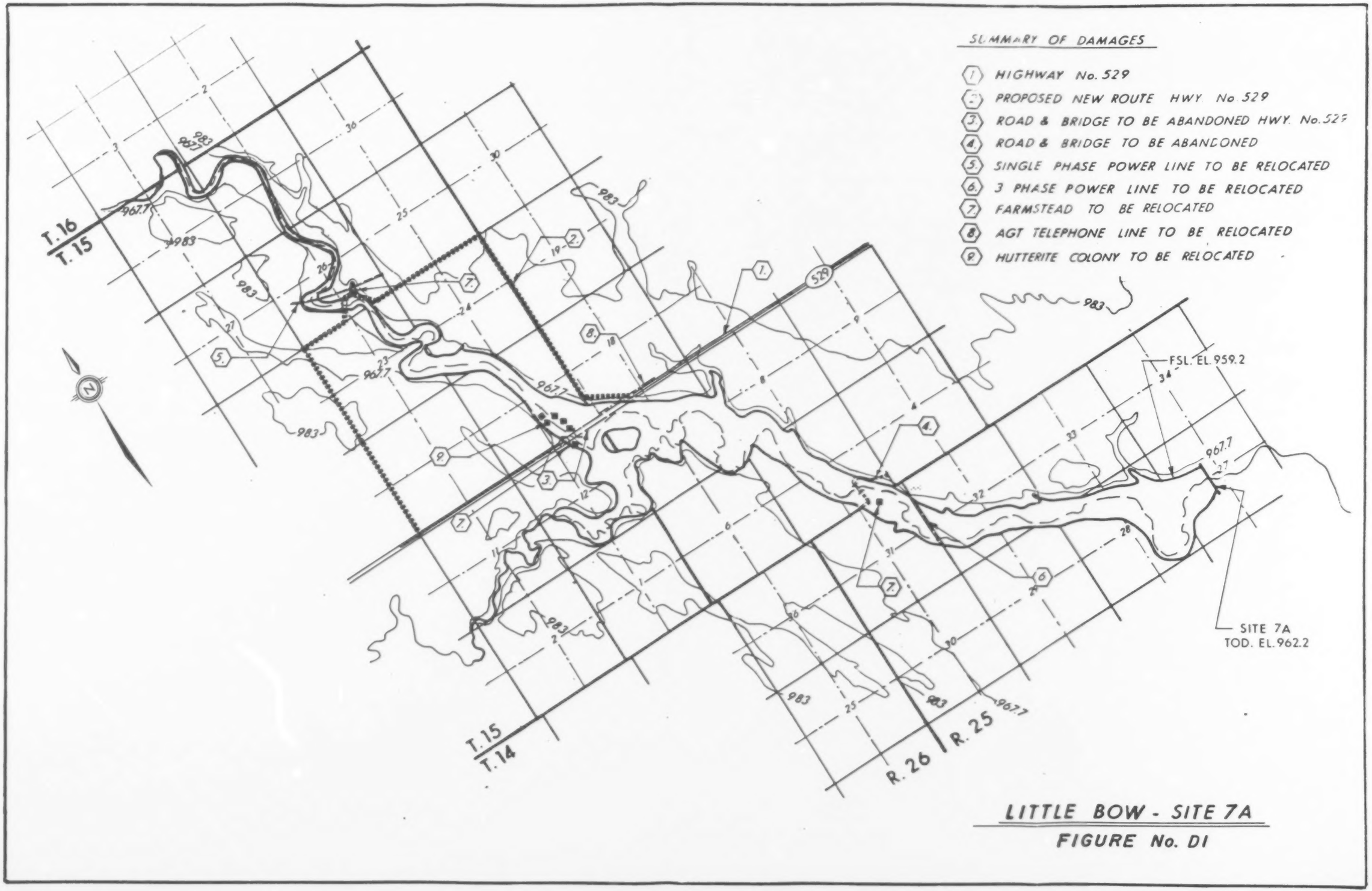
Relocation of the Bow River Hutterite Colony is estimated to cost $800,000.

d) SE 26-15-26-W4

Relocation of these farm buildings is estimated to cost $80,000.

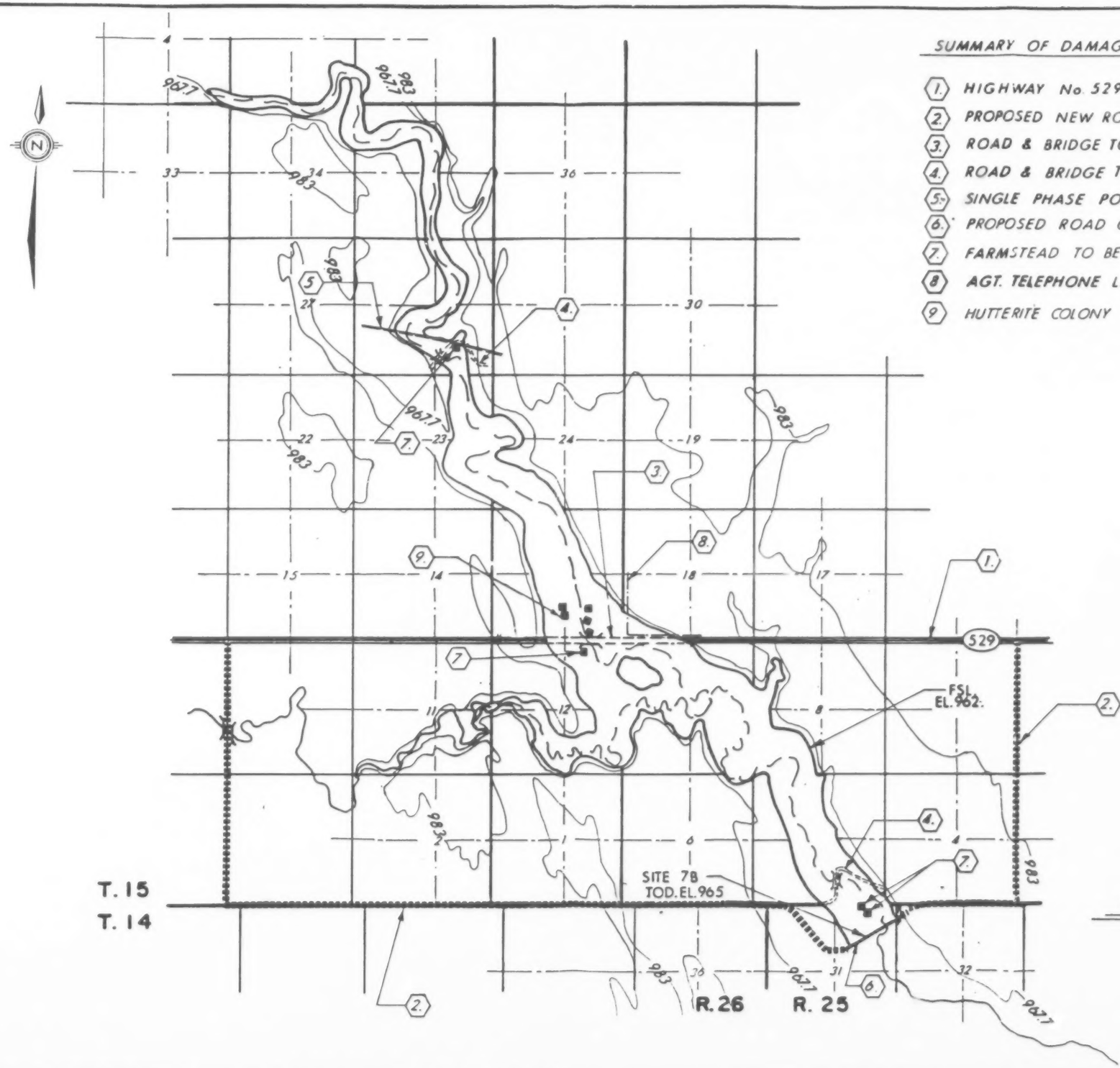
Reservoir Cost Summary

Land Acquisition		$1,309,000
Roads		1,300,000
Utilities		70,000
Farm Buildings		1,010,000
	TOTAL	$3,689,000



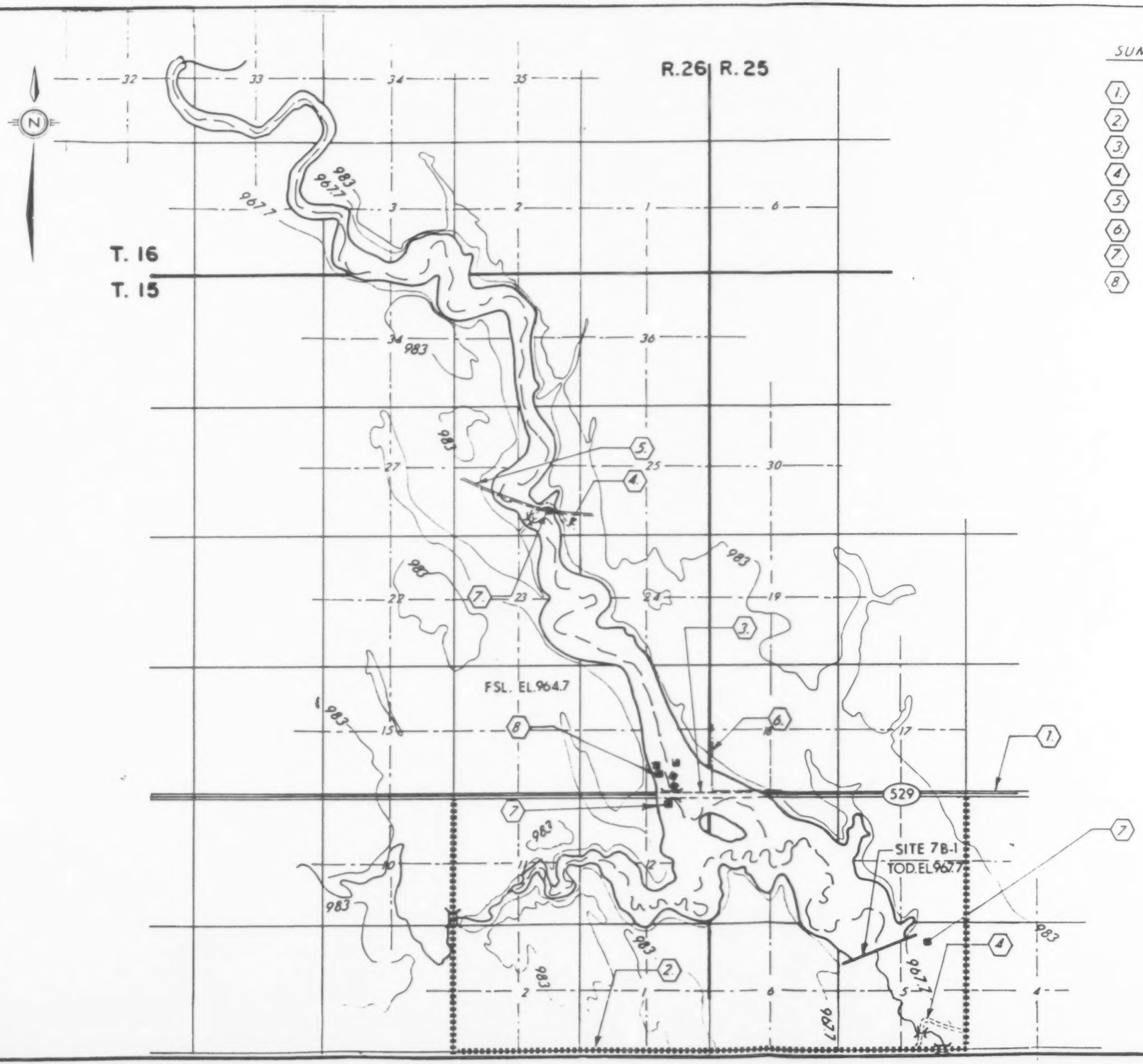
LITTLE BOW - SITE 7A

FIGURE No. D1


SUMMARY OF DAMAGES
1. HIGHWAY No. 529
2. PROPOSED NEW ROUTE HWY. No. 529
3. ROAD & BRIDGE TO BE ABANDONED HWY. No. 529.
4. ROAD & BRIDGE TO BE ABANDONED
5. SINGLE PHASE POWER LINE TO BE RELOCATED
6. PROPOSED ROAD ON TOP OF DAM
7. FARMSTEAD TO BE RELOCATED
8. AGT. TELEPHONE LINE TO BE RELOCATED
9. HUTTERITE COLONY TO BE RELOCATED
N
967.7
983
529
FSL EL. 962.
SITE 7B TOD. EL. 965
T. 15
T. 14
R. 26
R. 25

LITTLE BOW - SITE 7B

FIGURE No. D2



SUMMARY OF DAMAGES

1. HIGHWAY No. 529
2. PROPOSED NEW ROUTE HWY. No. 529
3. ROAD & BRIDGE TO BE ABANDONED HWY. No 529
4. ROAD & BRIDGE TO BE ABANDONED
5. SINGLE PHASE POWER LINE TO BE RELOCATED
6. AGT. TELEPHONE LINE TO BE RELOCATED
7. FARMSTEAD TO BE RELOCATED
8. HUTTERITE COLONY TO BE RELOCATED

LITTLE BOW - SITE 7B-1

FIGURE No. D3